Unconventional Monetary Policy and Income Inequality in the U.S.

Master thesis Applied Economics and Finance

2017

Copenhagen Business School
MSc Applied Economics and Finance
Supervisor: Chandler Lutz

Hand-in date: 15th May 2017
Pages (incl. table of contents): 97
Characters: 165 601

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Abstract

When the zero lower bound became binding in the United States in 2008, the Federal Reserve implemented a range of unprecedented monetary policy instruments to revive the economy. The side effects of these new policy tools are consequently unknown territory, which has raised widening concern that unconventional monetary policy has contributed to exacerbated economic inequality. The purpose of this thesis is to discuss and analyze the distributive income effects of unconventional monetary policy in the United States. In order to address the distributional consequences of the policy further, we estimate a vector autoregressive model for the period between the end of 2008 and 2015. This thesis focus on indicators of the stock and labor market as channels in which monetary policy might affect the income gap. To identify unconventional monetary policy shocks, we apply a shadow rate for the Federal Reserve rate. The income inequality is measured with the Gini coefficient and 90/10 ratio, which are calculated using data from the Consumer Expenditure Survey.

Our results indicate that *i)* unconventional monetary shocks contributes to an increasing disparity between income groups. In particular, we provide evidence that the Gini coefficient and the 90/10 ratio rise significantly following a negative shock to the Shadow Federal Funds rate. Households at the different ends of the income distribution respond heterogeneously to monetary policy shocks. Further, our empirical results indicate that *ii)* the stock market is likely to have an augmented effect on the widening gap. We also find evidence that *iii)* the employment-to-population ratio rises following a negative shock to the Shadow rate and argue the labor market to be a stabilizing factor during such a policy regime, by compressing the income gap. *iv)* Finally, our findings suggest that unconventional monetary policy shocks explain a larger share of the changes in the income distribution than monetary policy during conventional periods.

Acknowledgement

We would like to express our gratitude towards our academic supervisor, Chandler Lutz, for his support throughout this writing process. We are grateful for his suggestions and guidance over the past few months, which has been key to the completion of the thesis.

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1 Introduction

The Federal Reserve implemented a range of unprecedented measures in the wake of the financial crisis of 2007. In order to stimulate the economy beyond the already low Federal Fund target range, measures such as quantitative easing and forward guidance were initiated. These measures intended to expand the balance sheet of the Federal Reserve, re-balance its composition as well as alter expectations of long-term interest rates. Being unconventional measures, research on the implications of these is currently scarce. Nor is the impact of the policy on the different parts of the economy fully explored. In 2014, the Chairwoman of the Federal Reserve, Janet Yellen, expressed her concern related to the exacerbated inequality (Yellen 2014). Attention has been drawn to whom in the society the measures potentially would benefit. Hereunder, the main concern involves that the nontraditional policies would only gain those on the high end of the income ladder and consequently unevenly distribute the positive effects of an expansionary monetary policy.

The target range for the Federal Reserves policy rate reached the zero-level in December 2008. This level for the short-term nominal interest rates is referred to as the zero lower bound (ZLB), due to the restraint that nominal interest rates can not enter the negative territory. At this limit the monetary policy is caught in a liquidity trapThe importance of evaluating monetary policy at this bound is likely to become increasingly relevant in the near future. With inflation below the inflation targets of many central banks, the nominal rates in several advanced countries are likely to persist at relatively low levels in the periods to come (Kiley & Roberts 2017). The possibility of more frequent encounters with the ZLB, accompanied with the potential costs of these scenarios, serves as enhancing motivation to investigate further.

Furthermore, the income gap between American households has been rapidly rising during the last four decades. Although this is true for several advanced economies, income inequality in the United States prevails at a higher level than most of its economic equivalents. Even more interesting is the fact that the inequality appears

to be driven by a strongly increasing income at the upper end of the income distribution. Numbers from Consumer Population Survey (CPS) estimate that the 90th percentile of the income distribution in the United States in 1975 earned 8.5 times as much as the 10th percentile. Four decades later this multiplier escalated to 12.2. 30% of this increase occurred in the period between 2009 and 2015 (Proctor et al. 2016). Monetary policy is assumed to have consequences for several macroeconomic variables, however economic equality is not in the objectives of the Federal Reserve. Assuming that monetary policy affects the incentives and well-being of households in an economy, there are several channels in which this policy might show a distributional impact.

With limited previous research within this field, this paper strives to contribute to the discussion concerning the effects of unconventional monetary policy on income inequality. Our paper contributes by using higher-frequency income inequality measures, which are based on a comprehensive household survey, and estimated quarterly. Additionally, we apply a shadow rate for the Federal Reserve rate as a proxy for the stance of unconventional monetary policy. To our best knowledge, this measure has not previously been applied in the studies of distributive effects.

To assess the relationship between monetary policy and income inequality, we employ a vector autoregressive (VAR) model. To measure the stance of the monetary policy in the United States at the ZLB, the Shadow Federal Funds rate by Wu & Xia (2016) is used. In order to evaluate the income disparity, two different measures are applied, namely the Gini index and the 90/10 ratio. Both measures are calculated based on household income data from the Consumption Expenditure Survey. Different income compositions between households, through labor and financial income, accounts for some of the proposed channels in the monetary policy transmission mechanism to income inequality. Therefore, income inequality measures are calculated using both income sources: wages and total income of households. To shed light on some of the channels in which monetary policy might induce inequality, the stock market and labor market effects are examined further.

1.1 Problem Statement

This thesis is designed to answer the following question:

What are the effects of unconventional monetary policy on income inequality in the United States?

1.2 Delimitations

We will examine the issue by using different measurements of income inequality. Our motivation is to uncover potential distributional side effects induced by unconventional monetary policy stimulus. Due to limited research on the field, this policy regime will be our focus. Its conventional counterpart is described and investigated with the intention of using it as benchmark for comparative measure.

The paper also attempts to identify the channels in which monetary policy induce changes in income disparity. Several channels are proposed to explain the different underlying mechanisms. However, the scope of this thesis is limited to the assessment of the overall effect of monetary policy on income inequality, through empirical analysis and discussion around these potential channels. That is, we do not intend to evaluate the specific weights of the different channels.

Further, given that the unprecedented policies have been implemented during a limited time frame, the sample period ranges from the end of 2008 until late 2015. The sample period also restricts the thesis to focus on the short-run implications of the policy.

1.3 Thesis Structure

The thesis is structured as follows: *Section 2* starts with the theoretical framework behind monetary policy, decomposed into conventional and unconventional policies, and income inequality. The transmission mechanisms of the three will be especially

emphasized. *Section 3* and *4* are devoted to investigating monetary policy and income disparity in the United States, respectively. Thereafter follows an overview of the previous literature, which are presented in *section 5*. Insights gained from the previous sections will be used as base for the sections to come. *Section 6* provides the econometric framework, together with insights as to the source of where the different variables are derived. This section wraps up with an overview of the limitations of the estimated model and variables. The empirical results and analysis are presented in *section 7*, and these results are further discussed in relation to channels in which monetary policy might affect income disparity. Finally, *section 8* concludes the research and summarizes our main findings.

2 Theory

This section provides the theoretical framework of monetary policy and income inequality. In order to describe unconventional monetary policy, the theory behind conventional monetary policy will first be presented. The subsequent section describes unconventional monetary policy with the transmission mechanism in focus. The third part introduces income inequality, its relevance and different ways to measure the level of disparity. Conclusively, we present the channels in which monetary policy might induce income inequality.

2.1 Conventional Monetary Policy

2.1.1 Objectives

Monetary policy has a direct impact on the money supply in the economy and aims to promote price stability in the monetary value (Steigum 2004). A stable monetary policy will in general contribute positively to wealth, economic growth and employment (Gjedrem 2008) and is intended to boost confidence and increase predictability. This in turn makes it easier for the public to reach rational decisions and make plans for the future. Monetary policy builds on the same pillars across economies, however, objectives of the central banks might vary.

2.1.2 Instruments

The central bank can reach their aforementioned objectives through setting the overnight target interest rate for the interbank money market, in addition to buying and selling government bonds in order to adjust the money supply (Steigum 2004). Another traditional monetary policy tool is to modify the reserve requirements of the banks.

A central bank exercise these instruments in order to reach inflation and growth

targets. The main tool is open-market operations, where the central bank buys and sells government securities to alter the money supply. When committing to an expansionary monetary policy, the central bank increases the money supply in the market with the intention of stimulating the economy. The opposite is true for a contractionary monetary policy, which is practiced when the economy shows signs of overheating. Furthermore, purchasing of government securities is initiated as an accommodative measure, whilst selling is contractionary (Mathai 2012).

2.1.3 Transmission Mechanism

The transmission mechanism suggests a relationship between monetary policy decisions, the price level and other macroeconomic variables. It is meant as a simplistic model to present the mechanisms in which the policy might transmit throughout the economy (Galí 2008).

The first group of channels are denoted the *interest-rate channels*. In the Keynesian IS-LM model, an expansionary monetary policy decreases the real interest rate and reduces the cost of capital. Hence investment spending increases and aggregate demand and output rise. In the description by Keynes, the mechanism is focused on the rise of investment spending stemming from business, while newer research has additionally acknowledged consumer expenditure and housing decisions as investment (Mishkin 1996). Due to stickiness in prices, an accommodative monetary policy decreasing the nominal short-term interest rate will cause the real short-term interest rate to drop. According to the expectation hypothesis of the term structure, the long interest rate is equal to the average rate of the expected future short-term interest rates. Thus, decrease in the real short-term interest rates transmits into a decrease in the real long-term interest rates, which affects business fixed investments, consumer durable expenditures and housing investment decisions (Mishkin 1996). Monetarists see the explicit focus on interest rates, whilst neglecting other asset prices, as a limitation of the traditional IS-LM model (Mishkin 1996).

Another mechanism is the exchange rate channel, which describes the impact on net

exports of changing domestic interest rates. For example, a drop in the domestic interest rate makes domestic deposits less appealing compared to deposits denominated in foreign currency. The depreciation of the domestic currency yields lower prices of domestic goods relative to foreign goods. Thus, net exports increase and aggregate output rise (Mishkin 1996).

The equity channel is twofold: it is based on Tobin's q and the wealth impact on consumption. According to the Tobin's theory, monetary policy affects how equities are valued. The q is defined as the market value of firms divided by the replacement cost of capital. A monetary policy easing increases equity prices, which increases q and investment spending, which eventually generates a rise in output (Mishkin 1996). The wealth effects are linked to the ideas of Modigliani and his life cycle model, which states that consumption is based on total lifetime resources. If the central bank raises the money supply, the total financial wealth and resources of consumers will increase. Consequently consumption and output increase (Mishkin 1996).

The credit channel is described as the non-neoclassical channel and focuses on the imperfections of the credit market. The channel is usually divided into two main parts: the bank lending channel and the balance sheet channel [1]. The bank lending channel evolves from the idea that banks provide a solution to asymmetric information within credit markets. Without banks, a large share of borrowers would be left out of the credit markets. An accommodative policy enlarges the size of bank reserves and bank deposits, which again allows for the size of total loans available to grow. In consequence, investment and consumption rise (Mishkin 1996). The balance sheet channel describes a relationship between net worth of companies and moral hazard. A net worth reduction of a company implies a lower level of collateral for their loans which enhances the risk of moral hazard and adverse selection. Thereby lenders are more hesitant to offer loans, and aggregate demand and spending decrease (Boivin et al. 2010). An expansionary monetary policy which

[1] Older literature also focuses on a third channel: analyzing the impact of government interventions on credit supply. However this channel is less relevant today and will therefore not be discussed in this paper (Boivin et al. 2010)

increases the equity prices (through the equity channel), will boost the net worth of companies and provide a solution to the above mentioned problems. Consequently, investment spending and aggregate demand can rise (Mishkin 1996). The balance sheet channel also describes the impact of monetary policy on cash flows. A policy which makes nominal interest rates lower, boosts cash flows and hence mitigate the problems of moral hazard and adverse selection. As a result, lending and investment opportunities rise (Mishkin 1996).

2.1.4 Measuring the Stance of Conventional Monetary Policy

The Taylor Rule

The Taylor Rule is a frequently used guideline when central banks are setting their key interest rate. The rule stipulates how much the central bank should vary its key interest rate in accordance to changes in inflation and output (Taylor 1993). The rule articulates the trade-off between price and output stability expressed through the inflation and output gap, respectively. The intention behind the rule is systematic reduction of uncertainty, whilst increasing the trust towards the future monetary policy decisions of the central banks.

The rule have been altered and extended since it was first introduced, however, the original proposed Taylor-rule can be represented:

$$i = r^* + \pi^* + \alpha(\pi - \pi^*) + \beta(y - y^*) \tag{1}$$

where

i - nominal interest rate

r^* - neutral interest rate in equilibrium

α and β - reaction coefficients giving the weight attributed to the inflation gap and output gap respectively [2]

$(\pi - \pi^*)$ - π is actual inflation, and π^* is the inflation target, which together amounts

[2] Originally, the reaction coefficients, alpha and beta, was set to 1.5 and 0.5 respectively.

to the inflation gap
$(y - y^*)$ - y is actual output, and y^* is potential output, which together amounts to the output gap (Lønning & Olsen 2000).

The rule proposes that in a scenario with inflation higher than the inflation target and a positive output gap, the central bank ought to set the interest rate higher than the neutral real rate. As a result, the inflation will be led closer to the target and the output gap will be closed. Further, the rate will in the opposite situation be set lower than the neutral real rate. In a situation where both inflation- and output gap are closed, the Taylor-rule suggests a rate equal to the sum of the neutral real rate and the inflation rate (Woodford 2001). The trade-off between stabilization of inflation and output fuels conflicting views as to which policy is perceived as the most ideal (Galí 2008). Different central banks thus target these variables to different degrees.

Experiences made in the wake of the financial crisis of 2007 to 2008 have highlighted one of the limitations of such simple rules. Central banks started to cut their key interest rates at a much higher pace than previously, to the level where the nominal rate could not be decreased any further. Thus, in the presence of this ZLB of the nominal rate, the Taylor-rule appeared insufficient as a guideline for monetary policy (Galí 2008). That is, when the economy is facing low short-term interest rates, but still is at a stance where it needs further stimulation. At this economic stance, the Taylor-rule predicts a negative nominal interest rate, but is bound by the constraint (Bernanke 2015*b*). Among others, Kiley & Roberts (2017) have investigated simple monetary policy rules in the ZLB environment. They find that with low real interest rates, simple rules, such as the Taylor-rule, suggest paths for the economy that lead to worse economic performance.

2.2 Unconventional Monetary Policy

Several economies reached unprecedented levels of their nominal rates, making their first encounters with the ZLB in the aftermath the financial crisis. When conventional monetary policy became insufficient, more unconventional actions were conducted instead of, or in addition to, the more traditional ones. The main instruments are: quantitative easing, credit easing and forward guidance. These measures have a common objective of affecting long-term interest rates (Wu & Xia 2016). The following section describes these tools, focusing on the mechanisms behind them. Finally, a way to measure the stance of unconventional monetary policy is introduced.

2.2.1 Quantitative Easing

Quantitative easing, also called large scale asset purchase program, is a type of monetary policy instrument where the central bank issue money and buy financial assets. By carrying out a quantitative easing program the central bank injects money into the economy, increase asset prices and reduce the cost of borrowing (Bank of England 2017). A variety of quantitative easing programs have been implemented by the Bank of Japan, Bank of England, The European Central Bank and the Federal Reserve.

Quantitative easing is described as a conventional unconventional instrument, due to the similarities between quantitative easing and normal conventional mechanisms. However, there are differences as to how the mechanisms work. When the central bank buys long-term assets, the objective is to directly affect long-run interest rates. On the other hand, conventional monetary policy alters short-term interest rates, which due to changes in expectations of the short-term interest rates have an impact on the long-term rates. A distinction between quantitative easing and conventional monetary policy can be found in the scale of purchases and the circumstances in which quantitative easing is implemented (Bowdler & Radia 2012).

In response to an economic crisis, quantitative easing can contribute to stabilizing the economy. Furthermore, by undertaking quantitative easing programs, the central bank is able to perform monetary stimulus also at the ZLB. By increasing the size of its balance sheet, the central bank affects the quantity of money. Additionally, the balance sheet of the participants in the transaction is changed, including the banking sector and the non-bank private sector, such as pensions funds and insurance companies. When the central bank purchases long-term bonds or other assets, the trade is often financed by issued reserves held by commercial banks. The payments are made by crediting the sellers account rather than printing money. Thus, holdings of bank deposits increase, causing growth in the level of broad money (Bowdler & Radia 2012).

The next subsection takes a closer look at the transmission mechanism of quantitative easing, emphasizing the role of the portfolio channel, the signaling channel and the liquidity channel.

Quantitative Easing Transmission Mechanism

Quantitative easing affects the economy through different channels. The main effect is evident through the portfolio re-balancing channel. When the central bank purchases assets, it affects the portfolio of the seller (Gagnon et al. 2011). The portfolio re-balancing channel describes the implications of re-balancing the balance sheets of the private sector. When selling assets to the central bank, the characteristics of the seller's portfolio naturally change. As a result of the transaction, the private sector seller has bank-deposits instead of bonds.

When the interest rate reach the ZLB, the difference between money and one-period bonds are marginal, since the assets bear small credit risk. Consequently, when the central bank buys these bonds, the money creation is an insufficient monetary policy instrument to affect the economy. However, when purchasing long-term bonds or other assets that are imperfect substitutes to money, the effect of quantitative easing on the market is evident (Bowdler & Radia 2012). Large asset-purchases will affect the supply and yield of the asset. Further, there is a chance that the seller try to

purchase other assets that are similar to the one sold. This can be explained by the fact that money is not a perfect substitute of the asset. Consequently, prices of the asset and its close substitutes will rise, and the yields will decrease (Hausken & Ncube 2013).

In addition to the portfolio re-balancing channel, previous literature discusses the way unconventional monetary policy transmits into the economy through the signaling and liquidity channels. In the presence of large impairments within the financial market, investors seek higher returns on assets for the risk of not being able to sell. Consequently, asset purchase programs can improve the liquidity of the market and reduce the liquidity premia, known as the liquidity channel (Bowdler & Radia 2012). In contrast, the signaling channel discusses the role of commitment, future direction and confidence of the central bank. When a central bank expresses its outlook foe the economy and choose to implement quantitative easing, the central bank also expresses its commitment to policy mandate, which affects expectations (Bowdler & Radia 2012).

2.2.2 Credit Easing

Quantitative easing differs from credit easing as the former does not set restrictions to the composition of the balance sheet. Credit easing, on the other hand, focuses on a target composition of the balance sheet (McMahon et al. 2015). Exercising this tool, the central bank intervenes in the market and changes the composition of the balance sheet, by selling and buying different financial assets. Consequently, the available sources and costs of credit in the market change. With an increasing demand for a financial asset, there is less supply left for private investors. Therefore, prices will also increase and the yield decrease.

For the purchases and sales to be effective, the assets bought and sold should not be close substitutes. In fact, the larger the differences between the yields of the assets, the more likely it is to have an impact. A concern with credit easing is that it benefits the users of credit differently. Further, as a monetary policy tool, there

are uncertainties related to the real effects (Cecchetti et al. 2011).

2.2.3 Forward Guidance

Forward guidance concerns the announcements and communications made by the central bank regarding the future direction of monetary policy. The purpose is to encourage consumer spending and investment for both individuals and companies, in addition to reducing uncertainties about the future. Hence, these announcements can have an immediate impact and is defined as a an unconventional tool (The Federal Reserve 2015c).

Forward guidance may be initiated as an instrument at the ZLB when conventional instruments become insufficient. The objective is to provide indications about a low future rate and thus stimulate the economy. Filardo & Hofmann (2014, p.37) describe three main prerequisites in order for forward guidance to be an effective mechanism: *"i) seen as a commitment; ii) clearly communicated; iii) interpreted in the way intended by the central bank"*.

The first requirement states that the public must perceive the announcement as a commitment: to alter the expectations and decisions of the public, they must be confident that the central bank will do as promised in the future. The second and third requirement are closely connected. First, it is important that the announcement is clearly communicated. In particular, it is crucial that the public understands the aim of the policy, the time frame of the future policy, as well as which conditions that must hold. In case of high level of complexity, the central bank risks misinterpretations among the public and that the market will react accordingly. The central bank has to be able to explain its evaluation of the economic outlook and the reasoning for its policy. If the market interprets the policy differently from the central bank, the market response can be contrary to what was intended (Filardo & Hofmann 2014).

According to Plosser et al. (2013), policy makers need to be cautious when an-

nouncing a future policy path commitment. They should be prepared and capable to respond to economic shocks. There is a trade-off between commitment to a policy path and the power to make policy decisions without any restraints (Plosser et al. 2013).

Forward guidance is closely connected to the idea of transparency and clear communication within policy making. When expectations of the public are aligned with the future path of monetary policy, it enhances a higher level of stability within the financial markets and facilitates decision-making for consumers related to investment, consumption and employment (Plosser et al. 2013).

Plosser et al. (2013) argue that there are two main channels of forward guidance. The central bank affects inflation expectations through signaling commitment to a monetary policy. Higher expectations towards inflation can reduce real interest rates. Consequently, consumers prefer to save less and increase their spending, which provide a boost to consumption today. The other channel relates to consumers' expectations about the economic outlook for the years to come. When the central bank commits to a low short-term rate over a longer horizon, people expect increased growth and a brighter future for the economy. The public perceives this as an opportunity to raise current consumption, and save less. (Plosser et al. 2013).

2.2.4 Measuring the Stance of Unconventional Monetary Policy

When the policy rate is constrained at the zero level, measuring the overall stance of the monetary policy poses several challenges compared to traditional monetary policy. In this scenario, the monetary base is frequently used as measurement. Another measure of the stance is a shadow rate, that tracks a hypothetical key interest rate, capable of going into the negative territory. We will investigate such a shadow rate for the United States economy in *section 3*.

2.3 Income Inequality

In this paper, we define income inequality as a notion of income disparity between people or households. The uneven income distribution is often represented in the form of the gap between low-income versus high-income groups.

2.3.1 Why Income Inequality matters

Income disparity has become a widespread concern for many developed countries the last decades. Many developed countries experienced high income inequality in the beginning of the 20th century. Then, around 1920 followed a period with compressed inequality between rich and poor. However, the trend reversed around the 1980's, with slowly increasing inequality. Piketty (2014, p.223), in his book "*Capital in the 21st century*", presents data suggesting exactly this U-shaped development in the United States and Europe [3]. The two economies follow the same trends, but when the inequality starts increasing from 1980, the gap between the two widens, with the United States notably more inegalitarian. Currently, both developed, as well as developing countries, are witnessing increasing inequality (Keeley 2016). Following this development, research on income inequality has surged.

While many will agree in favor of tightening the income inequality gap, there are also voices which argue some inequality in a society to be beneficial, at least to some extent. The backbone of this argument lies in the necessity of incentivizing entrepreneurship. Kuznets (1955) studied the relationship between income inequality and economic growth. In his paper, he proposes that inequality will rise in early stages of economic growth, and then start to diminish along with advancements in economic growth.

On the contrary, several empirical studies suggest that income inequality stall economic growth in addition to having a negative impact on social mobility and educational opportunities (Keeley 2016). Several studies, such as Brueckner & Lederman

[3]The inequality is measured by Piketty (2014) as the top decile as share of total income

(2015), find that income inequality has a negative effect on GDP per capita, also in the long-run. Brueckner & Lederman (2015) investigate the case for 140 countries during the period of 1970 to 2015. The authors find evidence that suggests that an increase in the Gini coefficient of 1 percent will, during a five period, decrease GDP per capita by 1,1 percent. The study additionally finds a positive relationship between income inequality and GDP per capita in poorer countries.

2.3.2 Measuring Income Inequality

There are several methods available to measure income inequality. Due to various data collection methods and differences in choice of inequality proxies, the measures are subject to deviating estimates. Studies on the issue consequently reach different conclusions. The most common measurement types are indices and ratios. Both provide useful information, however, they are recognized as fruitful contingent on the context. Naturally they also suffer from limitations. Common indices are the Gini coefficient, Hoover index and Atkinson measure. Ratios might compare different combinations of income groups, with the most common being 90/10, 80/20 and 90/50 ratios.

This paper will focus on one of each type, namely the Gini coefficient and the 90/10 ratio. In the following, the reader will be presented to the above-mentioned measures and a brief overview of their associated strengths and weaknesses.

One of the most cited indices used for income inequality is the Gini coefficient (Galbraith 2012). The Gini coefficient provides estimates on the overall distribution, that ranges from 0 to 1. The estimates can be understood as an indication as to how much the economy deviates from equality. Hereunder, an estimate of 0 suggest an economy with perfect equality, i.e. a scenario where every member (or household) of the population earns equal amount. Consequently, an estimate of 1 would imply that one person (or household) accounts for all income earned (Proctor et al. 2016).

This measure considers the whole income spectrum. Firstly, the Lorentz curve is

calculated by comparing the cumulative income share of people (or households) to the cumulative income share earned. This can be represented in a curve, called the Lorenz curve. Then, to reflect perfect inequality, a hypothetical 45-degree line which intersects the y- and x-axis at 100 percent is added. The Gini-estimate constitutes of the area between the 45-degree line and the curve, taken as a ratio of the total area under the perfect equality line. In *figure 1* the Gini coefficient is represented as the area A over the total area of A and B.

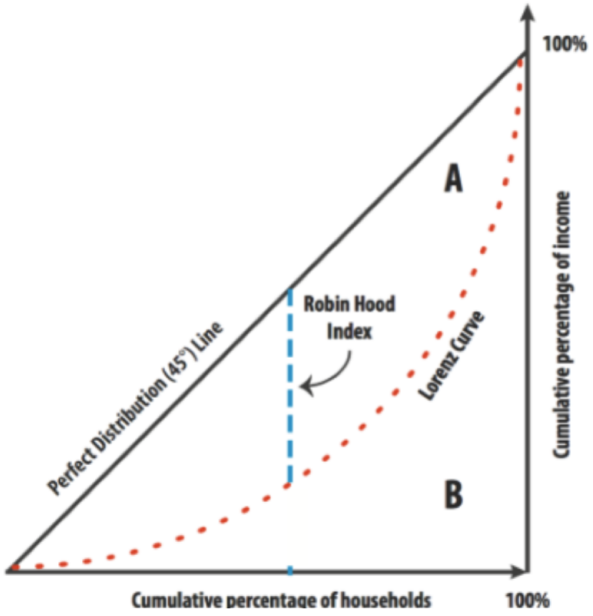


Figure 1: Measuring the Gini Coefficient

In technical terms, the Gini is calculated as followed:

$$G = \frac{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}|y_i - y_j|}{2\mu} \tag{2}$$

where

n - number of observations

y_i - household income for household i, sorted by smallest to largest

μ - average household (Kendall et al. 1946)

One disadvantage when inferring the Gini coefficient is that it is incapable of dif-

ferentiating between which end of the income distribution that accounts for the disparity. According to Rycroft (2013), the Gini coefficient is sensitive to the densest part, i.e. the middle part, of the distribution and relatively insensitive to the top and bottom part of the distribution. Even if the Gini coefficient reports a certain level of inequality, it does not provide further explanation for the drivers behind inequality nor which part of the population distribution is influencing the coefficient (Rycroft 2013). In other words, it is possible for highly different income distributions, for instance between countries, to report the same estimates of the Gini coefficient.

However, the Gini coefficient is advantageous in terms of being an easy-to-interpret and comparable index between different income distributions and is therefore often used to compare income inequality across countries (Galbraith 2012).

There are some alternatives to the Gini coefficient. One variant is the Hoover index, also known as the Robin Hood Index. This index measure is also based on the Lorentz curve. It measures the distance between the Lorentz curve and the "perfect distribution"-line, as shown in Figure 1. The name stems from the idea that the index measures the amount in which those over mean income would need to redistribute to those under mean income in order to establish full equality (Rogerson & Plane 2013).

The Atkinson measures are a range of indices that were introduced to add up for some of the limitations to the Gini coefficient. Using this index, the researcher sets a pre-determined value to a sensitivity-parameter in the formula that decides how much the index should be sensitive to the lower tail of the income distribution. That is, the researcher decides how much to weight the lower income groups in relation to the income distribution as a whole (De Maio 2007).

Another type of measure rather focuses at the specific parts of the income distribution. Income ratios explore the difference between certain defined income groups and are frequently used. This approach investigates an income group at the high end of the income scale towards a low-income group. Compared to the Gini coefficient,

this ratio is sensitive to the upper and lower tail of the income distribution. The estimate thus suggests how many times richer the richest percent in the population are compared to the poorest percent (Bank 2008). In this matter, a ratio of 1 would thus suggest perfect equality between the two groups, with inequality increasing together with a higher ratio. There are also various approaches as to how these ratios are calculated. One such practice compares the income at different percentile limits, expressed through a ratio. For instance, the 90th percentile gives an indication of the income level in which 10 percent of the population earns more than. Within this group, the 90/10 percentile ratio is frequently applied. This 90/10 ratio will then give an estimate of how much the 10 percent richest earn in comparison to the 10 percent poorest. The 90/50 ratio gives an estimate of the upper decile's share of income to the median (the 50th percentile) of the population. Another common method measures the average income in each of the two groups and calculates the ratio between them (Bank 2008).

By calculating the different income ratios, one can decompose the overall inequality effect and investigate whether potential changes are most apparent in the high- or low-income group. Another strength relates to the simplicity of calculation and interpretation. Nevertheless, the simplicity behind the ratio can also be perceived as a weakness. The ratio is not as informative as more complex measures. For instance, the ratio obscures the information of the income earners between the lower- and upper income groups. Hence, these earners are not taken into consideration. Moreover, since the ratio measures one income group against another, they are only expressed in relative terms. The ratios are consequently, in contrast to indices such as the Gini coefficient, not as suitable for comparison of economies (Bank 2008).

2.3.3 Income Inequality and Monetary Policy

As illustrated through the transmission mechanism, monetary policy affects the prices in an economy, both in terms of assets, goods and labor. For given heteroge-

neous agents, which differ in terms of income, portfolio composition, demographics, these monetary policy measures might have a distributive impact. Both when applied in traditional and nontraditional manner, monetary policy is likely to affect economic inequality to some extent.

There are limited previous literature on monetary policy and the distributive impact, as we will take a closer look at in *section 5*. However, the force of monetary policy can be studied closer by separating the effects into different channels. Coibion et al. (2012) discussed five main channels denoted: the income composition channel, the financial segmentation channel, the portfolio channel, the saving redistribution channel and the earnings heterogeneity channel. These were introduced in an attempt to decompose the different effects and forces which affect income inequality.

Income Composition Channel

The first channel argues that due to differences in income composition, households will respond differently to monetary policy decisions. Many households receive most of their income through labor earnings and are therefore sensitive to changes in wages. Nevertheless, some households rely on income from business profits and financial income. Further, given the assumption that it is the wealthier households that earn business and financial income (in addition to wages), and that a looser monetary policy shock will increase business profits more than wages, households with heterogeneous compositions will be influenced disproportionately. Consequently, this channel implies that expansionary monetary policy will benefit those who are exposed to financial and business profits and thus increase inequality.

Financial Segmentation Channel

The second channel assumes that people are connected to the financial market to different degrees. Due to this, changes in money supply due to monetary policy will initially affect those who have the strongest connection. With the assumption that this group earn more than those not interacting in the financial market, a looser monetary policy will according to this channel increase inequality.

Portfolio Channel

The third channel is described as the portfolio channel. According to Erosa & Ventura (2002), low-income households hold more currency compared to high-income households. The latter group tend to have a more diversified portfolio composition, thus being less vulnerable to inflation inducing monetary policy. Consequently, a rise in the inflation rate often translates into a transfer from low-income to high-income households, contributing to inequality.

Saving Redistribution Channel

Previous literature discusses the effects on savers and borrowers of changes to the interest rate. An increase in the interest rate is beneficial for savers, but hurts borrowers. The opposite effects are true for increase in unexpected inflation rate. Further, if savers are wealthier than borrowers, inequality between different households will rise.

Earnings Heterogeneity Channel

Labor earnings is the primary income source for most households. There are different reasons as to why low-income and high-income groups respond disproportionately to changes in wages through monetary policy shocks. One example is related to how unemployment falls upon low-income groups or rigidities in labor earnings for those in work. Households in the low-income brackets tend to be more sensitive to business cycle fluctuations. Despite this, these households usually receive a bigger proportion of their income from the government. These transfers are perceived more countercyclical, which implies that a looser monetary policy will have a positive effect on inequality (Coibion et al. 2012).

The three first channels imply, in contrast to the two latter, that expansionary monetary policy tends to increase inequality.

According to Furceri et al. (2016), the overall effect of monetary policy on income inequality is uncertain and it depends on the quantitative of the different channels.

Additionally, the transmissions also depend on the characteristics of the society. An expansionary monetary policy can potentially, through its influence on for instance assets prices and inflation, cause inequality to rise. As high income households are more likely to receive a higher level of financial income, an increase in prices for financial assets will therefore potentially increase the income inequality. Furthermore, low income households tend to have more liquid assets, as their main income channel is labor earnings. Keeping everything else constant, a higher inflation level increases the gap between low and high income households.

On the other hand, one could argue that an expansionary monetary policy would lead to less income inequality. An expansionary monetary policy will benefit borrowers, which are typically the less wealthy within the society. The opposite is true for savers. Also, according to Heathcote et al. (2010), labour earnings for the low-income households are more sensitive to a decrease in the level of economic activity. Hence, expansionary monetary policy will protect the low-income level of the distribution (Furceri et al. 2016).

The above discussion presents some of the contradicting factors which need to be taken into consideration when undertaking a policy action. There are also other factors which determine the distribution impact, such as the business cycle, country characteristics and the initial level of income inequality (Furceri et al. 2016).

3 Monetary Policy in the United States

In this section, we take a closer look at the monetary policy practiced by the Federal Reserve, together with the objectives and instruments of the central bank. In order to evaluate the more unprecedented measures of monetary policy in the United States, it is evident to draw lessons from the history of monetary policy. This section describes the measures taken before, during and after the economic and financial crisis of 2007-2008. Finally, we consider a common method to measure the stance of the unconventional monetary policy in the United States.

The Federal Reserve holds the responsibility of conducting the national monetary policy in the United States. In the United States, the statutory objectives for monetary policy are set by Congress and aim at stabilizing prices, maximizing employment and moderating long-term interest rates (The Federal Reserve 2016b). The Federal Open Market Committee (FOMC) is granted the responsibility to operate on the determined objectives. The FOMC includes the Board of Governors of the Federal Reserve System, the President of the Federal Reserve Bank of New York as well as four additional seats. These are rotating between the other Reserve Bank Presidents (Federal Reserve 2016*b*). In 2012, the committee announced a long-run strategy, stating that inflation should be targeted at a level of two percent yearly (Federal Reserve 2012*b*).

The Federal Reserve is an independent central bank. The members of the Board of Government are appointed for 14 years, with the aim of protecting the central bank from political influence. In addition, the government holds no voting power within the FOMC, no power to decide nor direct how the Federal Reserve should practice its policy (Bain & Howells 2003). Further, the Federal Reserve is self-funded, with the main income originating from interest on government securities. Yet, the Federal Reserve is a governmental actor and has an obligation to follow the objectives instructed by the Congress (The Federal Reserve R 2017R).

3.1 Instruments

Traditionally, the Federal Reserve has practiced three main instruments to achieve its objectives. The mechanisms consist of open market operations (OMO), adjustment of the discount rate and modification of the requirement of bank reserves. The FOMC is responsible for the first-mentioned instrument, whilst the two latter are regulated by the Board of Governors (The Federal Reserve 2017).

3.1.1 Open Market Operations

When engaging in OMO, the Federal Reserve buys or sells securities in the open market (New York Federal Reserve 2007). The Federal Funds rate represents the interest rates on borrowing of reserves between depository institutions (mainly banks) in the United States. These institutions are obliged to keep a certain amount in reserves, and lend from each other to meet these reserve requirements. The rate is consequently affected by the supply and demand for reserves in the economy. A supply that is higher than the demand translates into a lower Federal Funds rate and the opposite is true for a scenario with higher demand. By changing the money supply of reserves through OMO, the central bank is able to adjust the key policy rate, the Federal Funds rate, and in turn alter inflation, output and employment (The Federal Reserve 2004).

3.1.2 Discount Rate

The discount rate is the rate which commercial banks pay for loans from the regional Federal Reserve Banks and is set by the Reserve Banks and the Board of Governors. For commercial banks, the discount rate acts as a backup source of liquidity. Increasing the discount rate impacts other interest rates and works as a contractionary mechanism (St. Louis Federal Reserve 2017).

3.1.3 Reserve Requirements

Reserve requirements describe the fraction of deposits which banks are obliged to hold in cash. These are either cash held in vaults or at the Federal Reserve (Feinman 1993). From the perspective of the banks, there are no incentives to keep large reserves, as interest is not earned on these holdings (Bennett et al. 2002). At the same time, many banks meet their requirement almost solely through vault cash, which they may hold in absence of these regulatory restrictions, for their customers (Feinman 1993). In general, a higher reserve requirement decreases the available funds in the market for consumers and companies. Thus a higher requirement is a contractionary mechanism, whilst a lower requirement works accommodative (St. Louis Federal Reserve 2017).

3.2 Development of Monetary Policy in United States

Monetary policy in the United States has been constantly developing since it was first initiated. In the following we study this development. Considering that unconventional monetary policy became relevant after the financial crisis in the United States, the section starts with examining monetary policy during recessions.

3.2.1 Monetary Policy during Recessions

The Great Depression, from 1929 to 1939, largely influenced the American economy as well as the perception and role of monetary policy. Friedman & Schwartz (1963) argued that the Great Depression and its magnitude derived from inadequate monetary policy. The paper *"A monetary history of the United States, 1867-1960"* discusses the policy of the Federal Reserve at the time being and how the policy worsened the situation of the Great Depression. According to Friedman & Schwartz (1963), one of the mistakes was tightening the monetary policy prior to the stock market crash of 1929. Additionally, during the crisis the Federal Reserve raised in-

terest rates to prevent speculative attacks, which harmed domestic banks. Finally, Friedman & Schwartz (1963) argue that the Federal Reserve fell short on its role as lender of last resort and as a stabilizer of the banking environment.

Throughout the last nine recessions in the United States, the reaction of the Federal Reserve has been to cut interest rates, with an average drop of the rate of 5.5 percent. During the recession of 1981 to 1982 the Federal Funds rate dropped by more than 10 percent, which can be explained by higher average level of inflation and interest rates than today. According to Holston et al. (2017), the level of the Federal Funds rate, adjusted for inflation, has fallen by 2 to 3 percent from the 1980-1990s.

According to Reifschneider (2016), in the presence of a recession, evidence from previous recessions should be used with caution to draw the future path of monetary policy and optimal reaction to a future recession. The level of inflation, sensitivity of interest rate changes and the structure of the economy has changed, which might affect the implications of a policy intervention.

In the following we will examine the policies implemented before, during and after the financial crisis of 2007 to 2008.

3.2.2 Before Crisis

From late 1800's, long-run inflation was constrained by the Golden Standard. In the same period, changes in output and inflation had limited effect on short-term interest rates (Taylor 1999). From the establishment of the Federal Reserve System in 1914, when the Federal Reserve Act was signed, several policies have been exercised. However, guidelines for monetary policy were not established until the Banking Act of 1933 and 1935 (Hester 2008).

Since the 1980's, the financial system has evolved into a bigger and more complex system. After this transformation, monetary policy gained more attention and increased its importance at the expense of fiscal policy. In the United States, before the economic and financial crisis of 2007 to 2008, the Federal Reserve had primarily

practiced monetary policy using the interest rate. It was regarded as the most efficient instrument in order to stabilize inflation and the financial markets (Cömert 2013). In the United States, purchases and sales of Treasury bills were conducted, especially Treasury bills with three months maturity (Farmer 2012). At the same time, these purchases and sales were at a smaller scale than what were to come during the financial crisis.

The use of forward guidance was first conducted in the United States in August 2003 due to the risk of deflation. The FOMC announced a monetary policy accommodation for a considerable period. Forward guidance was initiated to influence the markets expectations in order to adjust it with the Federal Reserve's expectations (Philadelpia Federal Reserve 2013).

3.2.3 During Crisis

The Federal Funds target range was revised down in 2008 to a range of [0-0.25 percent] as observed in *figure 2*. The rate was kept low to stimulate the economy and boost investment and consumption after the financial crisis. The Federal Funds rate had not been at this level since the Great Depression of the 1930's. In 2008, the FOMC announced that due to poorer economic conditions following the crisis, the rate could remain low also in the years to come (The Federal Reserve 2015c).

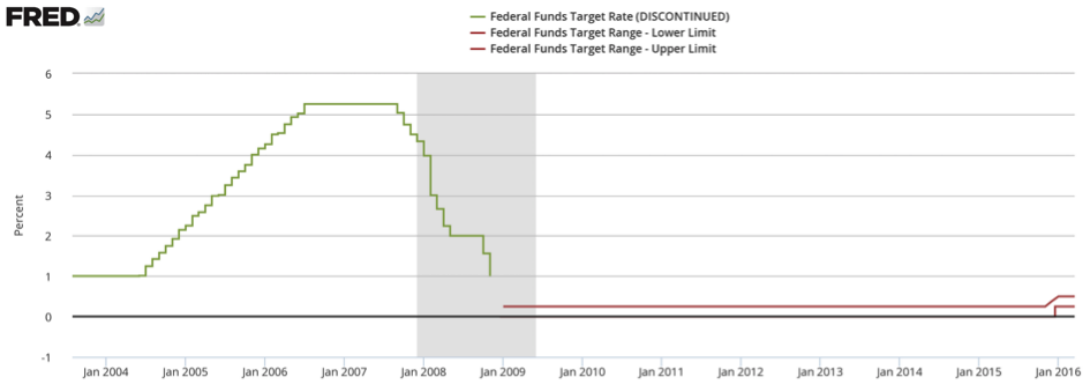


Figure 2: Federal Funds Rate Target Range
Source: Board of Governors of the Federal Reserve System (US) fred.stlouisfed.org. Shaded area indicates US recession

A further response to the crisis was the enforcement of credit and liquidity programs for financial institutions, which enlarged the size of the Federal Reserve's balance sheet (The Federal Reserve 2016z).

The Federal Reserve publicly announced the first quantitative easing program (QE1) in November 2008, as reported in *table 1.* QE1 consisted of the purchase of government-sponsored enterprise (GSE) debt for a value of 100 billion USD as well as mortgage-backed securities (MBS) of 500 billion USD. In March 2009, the QE1 program was additionally enlarged with 100 billion USD of GSE debt, 750 billion USD of MBS, as well as long-term Treasury securities for a value of 300 billion USD. The QE1 purchase program was aimed at stabilizing the economy, with a focus on the housing and credit markets. In total, approximately 80 percent of the asset purchases in QE1 were housing GSE debt and MBS (Fawley et al. 2013).

In late 2010, the Federal Reserve pursued another quantitative easing round (QE2) aiming at lowering the long-run interest rates and increase inflation. The QE2 consisted of further purchases of United States Treasuries at longer maturities, for a value of 600 billion USD. The announcement of the QE2, in contrast to QE1, was highly anticipated by the market and the asset prices were adjusted for this. In 2011, the Federal Reserve developed the Maturity Extension Program (MEP), called Operation Twist (OT). The central bank bought 400 billion USD long-term assets and sold 400 billions of USD short-term assets. (Fawley et al. 2013).

As a response to slow growth in non-farm payrolls, the Federal Reserve announced an extension to the MEP in 2012 of additional 267 billion USD. However, the labor market had staggered and the program did not meet its objectives. As a result, the Federal Reserve conducted a new round of quantitative easing, the QE3. The QE3 program differed from the previous rounds. Instead of a predetermined total quantity, the Federal Reserve announced a determined pace of purchases. The Federal Reserve committed to purchasing 40 billion USD MBS per month until the labor market had recovered (Fawley et al. 2013). In December 2012 the program was extended to include 45 billions of long-terms Treasuries (Federal Reserve 2012*a*).

Round	Date	USD	Assets
QE1	Nov 2008	600 bn	GSE debt, MBS
QE1 extension	March 2009	1150 bn	GSE debt, MBS, LT Treasuries
QE2	Nov 2010	600 bn	LT Treasuries
MEP (OT[4])	Sept 2011	400 bn	Purchased LT Treasuries and sold ST Treasuries
MEP extension	June 2012	267 bn	Treasury securities
QE3	Sept 2012	40 bn per month	MBS
Extension	Dec 2012	85 bn per month	MBS and LT Treasuries
Tapering	Dec 2013	-10 bn per month	Reduction of purchases

Table 1: Quantitative Easing and MEP Events
Source: Labonte (2013)

Additionally, the Federal Reserve employed forward guidance in 2012, giving indications of the future direction of the economy (The Federal Reserve 2015c). In contrast to the previous usage of forward guidance, the 2012 announcement focused on terms of economic indicators rather than a predetermined time frame. In detail, the policy was set conditionally on an unemployment rate below 6.5 percent and inflation below 2.5 percent (Philadelpia Federal Reserve 2013).

Bernanke (2009) describes the policy instruments implemented in the United States as a type of credit easing rather than a type of quantitative easing. In the speech made by Bernanke (2009), the former chairman argue: *"The Federal Reserve's approach to supporting credit markets is conceptually distinct from quantitative easing, the policy approach used by the Bank of Japan from 2001 to 2006. Our approach– which could be described as "credit easing" - resembles quantitative easing in one respect: It involves an expansion of the central bank's balance sheet. However, in a pure quantitative easing regime, the focus of policy is the quantity of bank reserves, which are liabilities of the central bank; the composition of loans and securities on*

the asset side of the central bank's balance sheet is incidental."

Looking back at the monetary policy actions carried out in the years following the financial crisis, there has been a pronounced change to the assets composition of the Federal Reserve, as presented in *figure 3*. Additional to the quantitative easing rounds and forward guidance announcements, the Federal Funds target rate was lowered from 5.25 percent to the range [0-0.25 percent] from August 2007 to December 2008 [5]

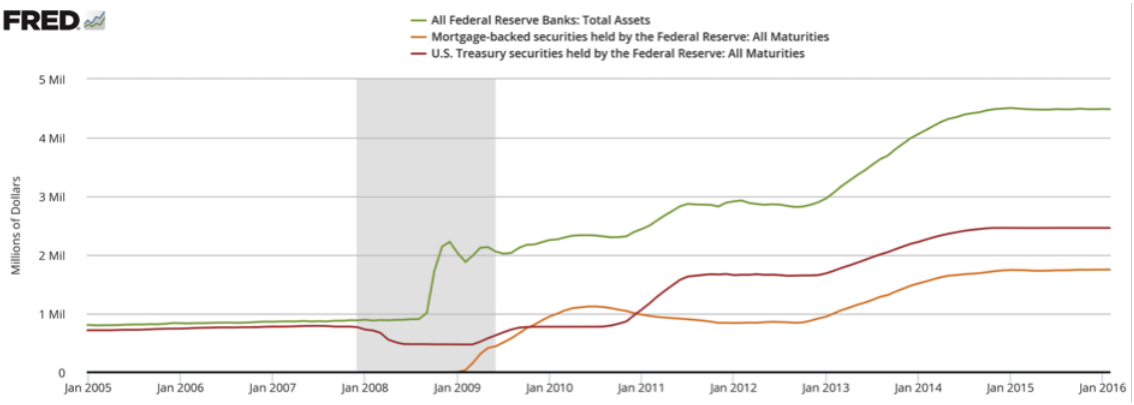


Figure 3: Assets held by the Federal Reserve
Source: Board of Governors of the Federal Reserve System (US) fred.stlouisfed.org. Shaded area indicates US recession

3.2.4 After Crisis

After conducting the large asset purchase programs, traditional monetary policy tools implemented prior to the crisis are no longer believed to be effective. Purchasing and selling assets through OMOs at a low scale in order to reach the Federal Funds target has lost some of its power (Ihrig et al. 2015).

At the beginning of May 2013, former Chairman Ben Bernanke indicated that the central bank would start to reduce its quantitative stimulus (also referred to as tapering). Then, in December the same year, the FOMC released that they would start to reduce the pace of the purchasing program, based on improved economic conditions, a more stabilized labor market as well as advancements in spending and

[5] As illustrated in *figure 2*

fixed investments (Federal Reserve of St. Louis 2013). In October 2014, the FOMC announced its conclusion of the asset purchasing program (Federal Reserve of St. Louis 2014).

During 2014, the Federal Reserve started preparations and discussions regarding how to normalize the monetary policy. A low target for the Federal Funds rate and short-term rates, in addition to a relatively large asset holding, served as motivation to prepare the path back to more normal levels. Some of the key points that the FOMC agreed upon were rising the target Federal Funds rate when appropriate, as well as reducing their assets in a timely and predictable manner (The Federal Reserve 2015y).

At the FOMC meeting in December 2015, the Federal Reserve stated that the economy now was at a stance where a normalization process could be initiated. To keep the Federal Funds rate at the target, the Federal Reserve started overnight reverse repurchase agreements in late 2015 (The Federal Reserve 2016x).

Kiley & Roberts (2017) and Del Negro & Tambalotti (2017), among others, argue the real interest rate to be currently low and that it will stay at this level in the long run. Del Negro & Tambalotti (2017) estimate the real rate to be approximately 1 percent, annually. Along with an inflation below target and low inflation expectations in the United States, they project the ZLB to be binding more frequently in the future, thus impeding on economic performance.

In FOMC Minutes (Federal Reserve 2016*a*) the Federal Reserve gave indications of an Federal Funds rate at approximately 3 percent in the years to come. Despite its projections of a higher Federal Funds rate in the future, the margin of the central bank to adjust its rate when faced with adverse shocks will still be limited due to the ZLB.

With the previous recessions in mind, the leeway for reducing the rate during recessions seem to be on the short side (Reifschneider 2016). As mentioned, comparisons with historical events are not likely to give a fair picture of the events to come,

however, the ZLB is argued to be a more frequent issue in the future. Additionally, Reifschneider (2016) argues that this limitation to the interest rate is likely to be accommodated with initiating quantitative easing and forward guidance also in the future.

3.3 Measuring Unconventional Monetary Policy in the United States

In the United States prior to the unconventional period, consensus was that the Federal Funds Rate was an informative proxy when measuring the stance of monetary policy (Bernanke & Blinder 1992). This view changed when the ZLB became binding, taking into consideration the scope of the additional monetary policy instruments implemented. This interest rate as an indicator of monetary policy stance was no longer perceived as accurate nor valid for monetary policy evaluations (Lombardi & Ravazzolo 2013). Lombardi & Ravazzolo (2013) document that using the Federal Funds rate as proxy for the monetary policy after hitting the ZLB would underestimate the monetary policy easing. As a way of evaluating its stance, several measures have been suggested. One of these is the shadow of the Federal Funds rate.

The Shadow Federal Funds rate was first presented by Black (1995) in his analysis of interest rates at the ZLB. This bound limits nominal interest rates to either be zero or positive, because people have the alternative to hold cash as a risk-free investment. Consequently, as long as cash is an option, there are no incentives to hold securities which bear negative interest rates, and currency will dominate the latter. In line with this thought, Black (1995) argues that the short-rate is an option as well. Thus, the "Shadow short rate" is defined as a process of the states; either zero or positive short-rate, or the hypothetically negative short-rate. Black subtracts the actual nominal yield curve from the estimated value of this call option of holding currency, in order to find the shadow yield curve (Christensen & Rudebusch 2014).

After the financial crisis of 2007-2008 the rate was developed further and applied among researchers for analyzing the impact of monetary policy actions (The Federal Reserve Bank of Atlanta 2016). Krippner et al. (2012) built on the research of Black (1995) and argued the Shadow rate to be an useful measure of the stance of monetary policy when interest rates reached the zero level. In 2013, Jing Cynthia Wu and Fan Dora Xia developed a model which provides estimates of the Shadow Federal Funds rate, describing the monetary policy in the United States, when the measures used were of the nontraditional kind [6]. Lombardi & Ravazzolo (2013) have also proposed their version of a shadow policy rate.

All the above mentioned versions of the shadow rate are shown to trace the actual Federal Funds rate quite accurately during conventional times. However, after hitting the ZLB, the rates of Wu & Xia (2016), Krippner et al. (2012) and Lombardi & Ravazzolo (2013) start to deviate. While Wu & Xia (2016) estimate a shadow rate that reaches its lowest level at a value of -3 percent, the shadow rate of Krippner et al. (2012) ranges down to -5 percent. The latter rate suggests that United States monetary policy has in fact been looser than the first measure indicates. Finally, the rate of Lombardi & Ravazzolo (2013) presents a more volatile pattern, with a maximum negative value of -5 percent. The paper also finds that the shadow rate drops until late 2009, then after the second quantitative easing program rebounds to above 0, then show an increasingly accommodative monetary policy, until late 2011 where it tightens strongly, to a level of -0.2 percent.

When the target Federal Funds Rate is bound by the zero limit, the Shadow Federal Funds rate can reflect the implications of other monetary policy instruments and evaluate the monetary policy stance in the same terms as the Federal Funds rate are expressed (The Federal Reserve Bank of Atlanta 2016). This property allows researchers to apply the Federal Funds rate, and use the the Shadow rate as an extension to the rate over both conventional and unconventional periods.

In the period from late 2008 to 2015, the effective Federal Funds rate target was

[6] In this paper, the Wu & Xia (2016) Shadow Federal Funds rate will be applied. See *subsection 6.2.4* for further details.

below 0.25 percent and in the so called ZLB range as pictured by the blue line in the *figure 4*. The green line illustrates the Shadow Federal Funds rate.

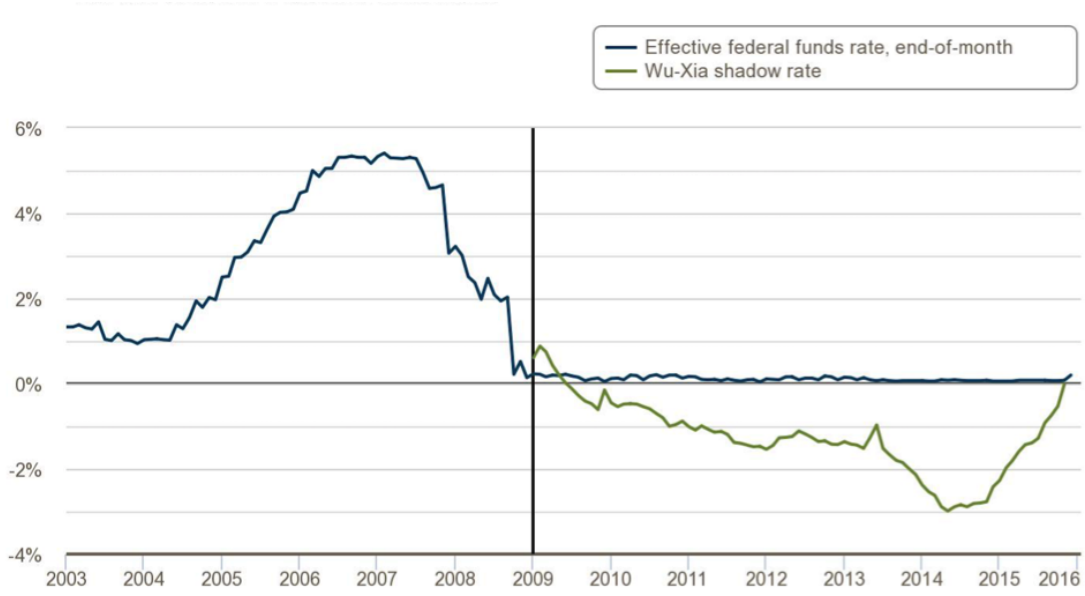


Figure 4: Shadow Federal Funds Rate
Source: Wu & Xia (2016) and Board of Governors of the Federal Reserve System

In the same way as Black (1995), Wu & Xia (2016) put as an underlying assumption that when the Shadow Federal Funds rate is above 0.25 percent, it is the equivalent to the short rate:

$$r_t = \max(\underline{r}, s_t) \tag{3}$$

where

r_t - short term interest rate
s_t - Shadow Federal Funds Rate
$\underline{r}$ - set lower bound at 0.25 percent

As for the estimation of the model of Wu & Xia (2016), one-month forward rate beginning in n years with n being respectively 0.25, 0.5, 1, 2, 5, 7 and 10 years are applied. In their model, the Shadow Federal Funds rate, s_t, is a function of state variables, X_t, characterized by a VAR(1) process (Federal Reserve Bank of Atlanta 2017).

Figure 5 provides the estimates of the Wu & Xia (2016) rate in the relevant period of

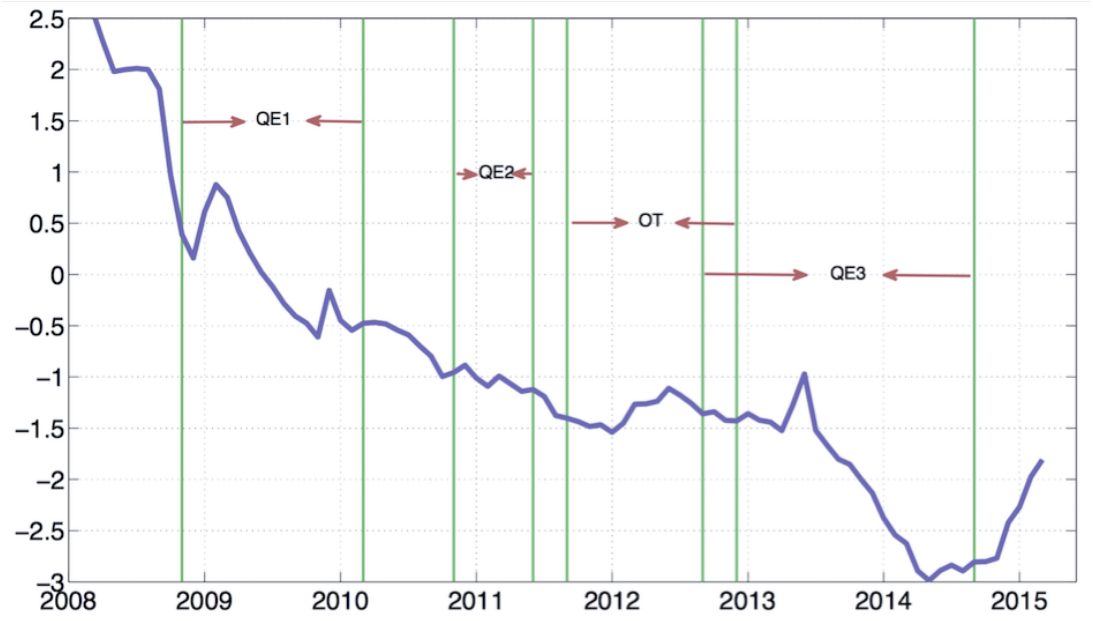


Figure 5: Shadow Federal Funds Rate and Asset Purchases
Source: Wu & Xia (2016, p.49)

unconventional policies in the United States. From the implementation of the first quantitative easing program (QE1) at the end of 2008 to March 2010, the Shadow rate decreased approximately 1.45 percentage points. In the next program of asset purchases, during the QE2, the drop in the Shadow rate was not as pronounced. This round was however of a smaller magnitude than the QE1. Additionally, as mentioned in *subsection 3.2.3*, the program was anticipated by the market. The Operation Twist (OT) of late 2011 lasted about one year. As displayed the figure, the Shadow rate only show a minor overall change during this interval. Lastly, in the period of the third quantitative easing program, the Shadow rate dropped a sizable amount. Despite drops in the Shadow rate during these programs, the Shadow rate might also have been subject to other factors than the programs alone (Wu & Xia 2016).

4 Income Inequality in the United States

The following section sheds light on the historical development of the income gap in the United States. To get the full picture of drivers behind income inequality, this section takes a brief look at other potential drivers of the disparity. That is, looking beyond monetary policy as main contributor of the changes in income distribution.

4.1 Development of Income Inequality in the United States

In the United States, the gap between low-income and high-income groups has been widening during the last decades. Compared to other OECD countries, the United States scores high on income inequality in 2015. Of these countries, only Mexico and Turkey are currently reported with higher income disparities, measured by the Gini coefficient (Keeley 2016). There are however great economic differences between the United States. and the countries with equivalent high inequalities. For instance, Turkey and Mexico have rather low GDP per capita. The United States, on the contrary, holds a relative high GDP per capita (Hoeller et al. 2012).

Another remarkable component of the inequality development, is the change to inequality during recessions and wars in the United States in the 20th century. Piketty & Saez (2001) provide evidence that during the First World War, the Great Depression and the Second World War, the income groups were affected relatively different than in the financial crisis of 2007. During these recessions, all income groups were influenced negatively, however the change in income were more severe for the top income groups whom to a higher degree relied on capital income, which were vastly influenced by the wars and recessions. Additionally, the highest income groups were also greatly affected by the taxation levels in war-periods. A higher corporate tax was imposed, which had an impact on the available income of those with capital. Meanwhile, the upper middle class, whose income source mainly consisted of high wages, were better off than the top income brackets (Piketty & Saez 2001).

Proctor et al. (2016) from the U.S. Census Bureau report an increasing trend in income inequality, measured by both the 90/10 percentile ratio and the Gini coefficient, during the period from 1967 until 2015 [7]. *Figure 6* reports the annual values of Gini coefficient during this period. Analogously, *figure 7* reports the changes in the income distribution for the same period.

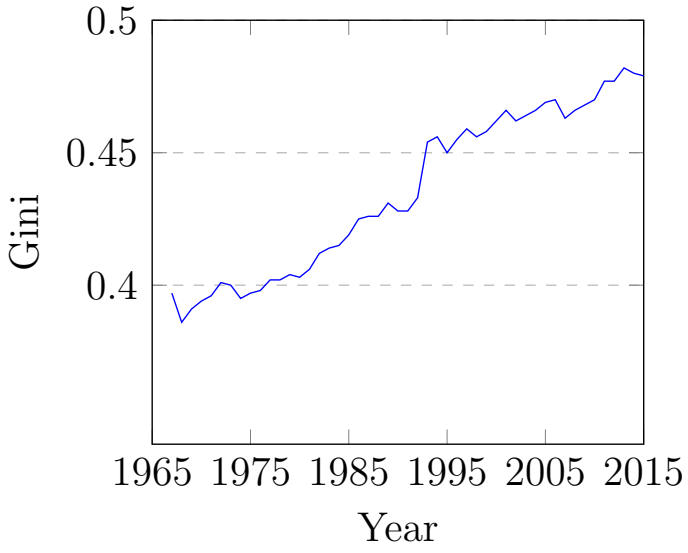


Figure 6: Gini Coefficient in the United States
Source: Calculated from Proctor et al. (2016)

According to Proctor et al. (2016), the Gini coefficient has been more or less increasing from 1974, where the index was 0.395. In the last reported year, 2015, the Gini coefficient was 0.479 after being on record-high levels in 2013.

According to *figure 7*, the gap has been steadily increasing from 1975. At this point the 90th percentile household in United States were approximately 8.5 times richer than the 10th percentile household. During this period, income inequality peaked in 2014, where the 90th percentile earned 13.2 times as much as the 10th percentile. In 2015, the ratio dropped to a level of 12.2. The changes in the gap between the two income groups is thus in contrast to the development in the beginning of the 20th century, where the richest percentage of the population were hit the hardest.

Consequently, both the Gini coefficient and 90/10 ratio provide evidence that overall resources have not been fairly distributed the last decades, and to an increasing

[7] based on data from CPS and Annual Social and Economic Supplement

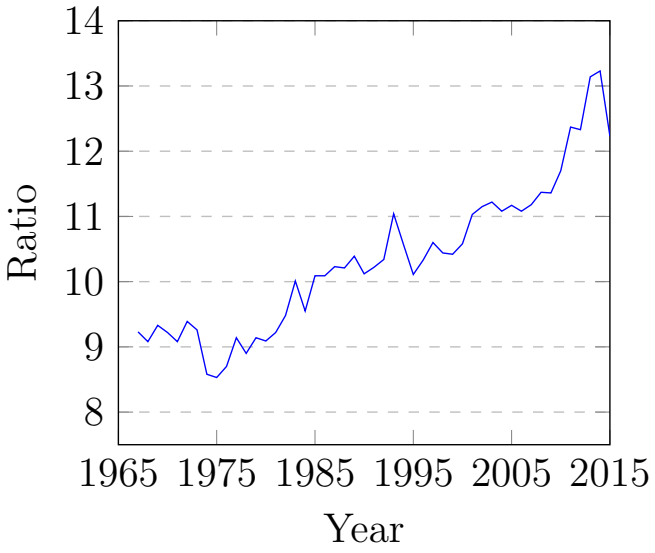


Figure 7: 90/10 Percentile Ratio in the United States
Source: Calculated from Proctor et al. (2016)

extent. This view seems to be the consensus in the majority of the research findings within this field (Burkhauser et al. 2009). By decomposing the income distribution further, this paper sheds some light on which part of the income distribution that has changed the most during the period. *Figure 8* compares the 90/10 percentile ratio to a 90/50 percentile ratio. In other words, the table presents the estimate of the 10 percent richest to the median income and compares it to the more extreme 90/10 [8].

Figure 8 shows that the rise in income disparity has increased more at the top than in the middle class and lower (Fisher & Smeeding 2016). Proctor et al. (2016) also report the 50/10, which evolves almost similar to the 90/50 percentile ratio.

Yellen (2006) has at several occasions expressed her concern for, and the importance of, the rising economic inequality. When the Federal Reserve President delivered a speech in 2006 to the Center for the Study of Democracy, she emphasized the fact that the recent decades' productivity gains seem to have been allocated mainly to one group in the society, the top income earners. This group has for the previous thirty years experienced a growth of approximately 30 percent, whilst wages for the median income group and below only grew at 5 percent. However, in the 1990's

[8] based on data from CPS and Annual Social and Economic Supplement

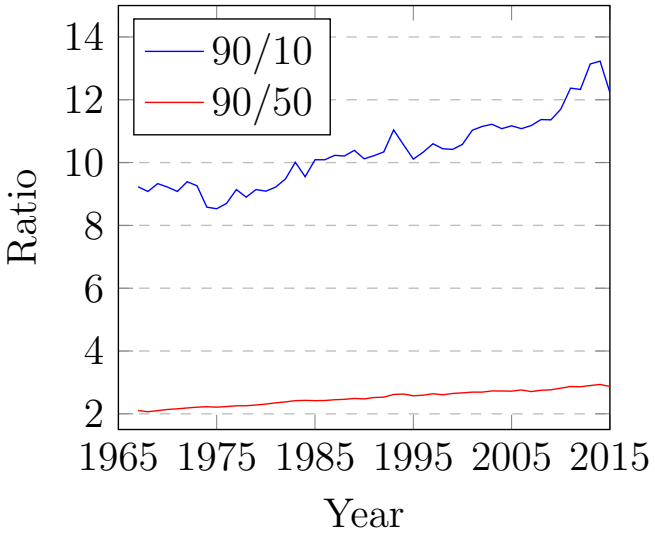


Figure 8: 90/10 versus 90/50 Percentile Ratio in the United States
Source: Calculated from Proctor et al. (2016)

the lower 10 percent experienced a significant growth in wages which tightened the gap between the lowest decile and the median income earners. The top 10 percent continued in the same fashion as before.

The top 1 percent of the income distribution has gained a lot of attention. Keeley (2016) reports that in 1980, this segment accounted for 8 percent of all income before taxes in the United States, while in 2012 they accounted for over 19 percent.

The data collected by Proctor et al. (2016) is based on survey data, which are known to have insufficient data on the top end of the income distribution. However, to investigate the top earnings, income data derived from income tax returns are recognized as better suited. Piketty (2014) uses this alternative income source. *Figure 9* shows the decomposition of the top decile in the United States. The figure provides estimates on the top 1 percent, the next 4 percent, and the 5 percent richest at the bottom of the upper decile and their percentage share of total national income (Piketty 2014). The top 1 percent evolves in the same pattern as Keeley (2016) suggested, almost doubling the percentage of total income from 1965 to 2015. Both the income earners between the 10 to 5 percent richest and the income earners between 5 and 1 percent are shown to have been slightly upwards sloping during the 45 years reported. The more striking observation is that of the top 10 percent

income earners, the top 1 percent seems be the main driver of the increasing top decile.

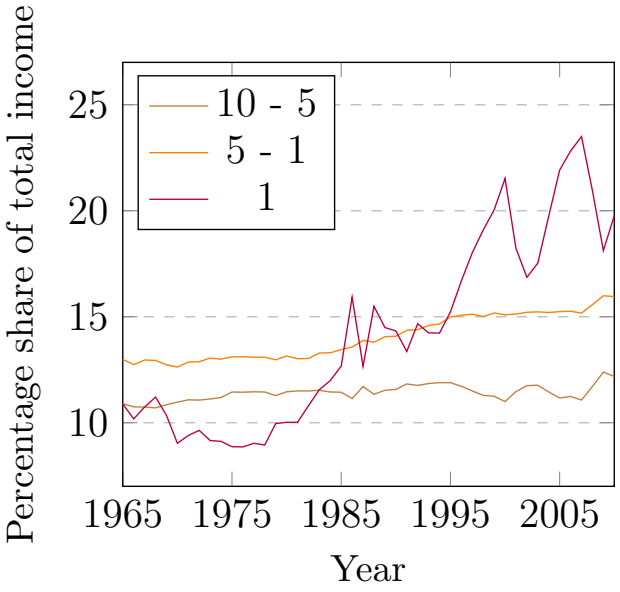


Figure 9: Decomposition of the Top Decile in the United States
Source: (Piketty 2014, p. 201)

4.2 Monetary Policy and Wealth Effects

Even though wealth inequality lies beyond the scope of this paper, some of the wealth effects will be briefly touched upon as wealth and income distribution are assumed to be closely connected. The channels influencing income inequality will be further analyzed in *section 7*.

As discussed in *section 2*, the *saving redistribution channel* underlines the disadvantage for savers and benefit for lenders, of lower interest rates or increased unexpected inflation (Coibion et al. 2012). Increased unexpected inflation makes the real value of households' debt smaller thus, all else equal, the mechanism decreases inequality. In the United States, interest rates have been low throughout the period, which according to the theory would hurt savers, which are typically the richer part of the population, and benefit the households with debt. Hence, all else equal, the channel contributes to less inequality.

There is a wide disparity in the net worth along the distribution of income. Net worth is described as the value of household's assets less the value of households liabilities (OECD 2017). *Figure 10* displays the net worth for all income quintiles in 2011. Within the lowest quintile, 31.2 percent had a zero or negative net worth. In comparison only 8 percent of the highest quintile had a zero or negative net worth. In addition, 33.8 percent of the highest income quintile had a net worth above $500,000. Hence, all else equal, the lower interest rate reduced inequality.

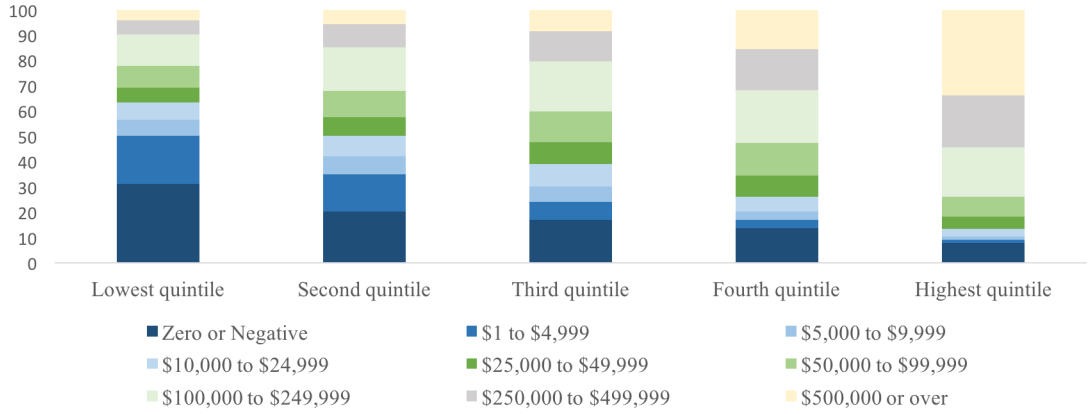


Figure 10: Household Net Worth Distribution (in percentage), 2011

Source: U.S. Census Bureau (2011)

On the contrary, in the *portfolio channel*, as the lower part of the distribution typically holds more cash, a policy which increase inflation will also increase inequality. However, according to (Bernanke 2015*a*) the effect is going to be relatively small for the case of the United States.

Finally, the difference in households' financial assets should be considered. In addition to the effects on stock prices, according to Bivens (2015), quantitative easing has increased house prices. Real estate accounts for a large share of the asset portfolio of the middle-class households. Consequently, the middle class households have also gained profit from the asset purchase programs of the Federal Reserve. However, lower income, and typically younger households, without real-estate assets will be worse off following a rise in house prices.

4.3 Potential Drivers behind Inequality

In this paper, we focus on the role of monetary policy as a contributing factor in the increasing income gap. However, inequality is also a product of other factors, which are not directly related to monetary policy.

In the United States, several factors have been identified as potential drivers behind income inequality, such as: opportunities of education, globalization, deunionization and changes in technology (Fisher & Smeeding 2016).

One of the possible drivers behind the recent inequality development is the profound gap in hourly real wage between those with no formal education, high school education, college education and more advanced educations. Globalization, through the channels of increased international trade, is also likely to have an impact on the inequality. In the United States, low-skilled labor tends to be imported, whilst the high-skilled labor is exported. Thus, the demand for the latter is increasing, which have the potential of widening the gap further. Skill-biased technology changes are also attributed some of the responsibility for the disparity. The idea is that there are wage disparities not only across different groups based on education, but also within these groups (Acemoglu et al. 2001).

The minimum wage in the U.S has staggered at a level of 7.25 dollars per hour since August 2009 (U.S Department of Labor 2017). The low level could potentially explain part of the disparate income distribution across households. According to Bureau of Labor Statistics (2016*b*), 78.2 millions receive hourly payments, which account for 58.5 percent of the total working population. 1.1 percent of the workers which were hourly paid received the minimum wage. Additionally, 2.2 percent of the hourly paid workers had wages below the set minimum (Bureau of Labor Statistics 2016*b*). These groups account for a small percentage of the total working population, and do not affect the broader income inequality measures significantly. However, when comparing the two extremes, the bottom and the top of the income specter, it is expected to have an influence.

5 Previous Literature

This section discusses the relevant empirical literature related to the link between monetary policy and inequality. Our paper focuses mainly on income inequality, however this section documents the previous literature on both income inequality and wealth inequality for a more nuanced picture. Due to the complexity of the way macroeconomic variables interact, this section will also state the different assumptions the authors of the papers have made in relation to the causality of the variables, i.e. the ordering of their VAR models, when applicable [9]*. Lastly, we will sum up the key takeaways from the literature, with the intention of utilizing this information in the following.*

Quantitative easing was carried out for the first time in the United States in 2008 and in the Euro area in 2015 (Bullard et al. 2015). Naturally, most studies on the topic are therefore relatively new. After the financial crisis, and the following Euro crisis, the Federal Reserve, the European Central Bank, Bank of England and Bank of Japan [10] developed different unconventional monetary policy programs. A variety of papers evaluate the effects on macroeconomic variables (Peersman (2011) and Meinusch & Tillmann (2016)) or focus on the financial markets (Rogers et al. (2014), Rosa (2012) and Joyce et al. (2011)). Furthermore, Farmer (2012) study the impact of monetary policies on inflation expectations and argue that unconventional monetary policy tools succeeded in stabilizing inflation expectations in the aftermath of the financial crisis.

Uncertainties connected to the role and efficiency of unconventional monetary policy are related to the fact that this is a relatively new type of policy. Additional concern for the cost of exiting quantitative easing has also been highlighted in Wen et al. (2014). The paper discusses the effects on the economy when the Federal Reserve starts selling assets back to the market.

[9] See *subsection 6.1* for further explanation of the ordering in structural VAR models.

[10] Bank of Japan initiated the first round of unconventional policies in 2001 (Saiki & Frost 2014)

5.1 Conventional Monetary Policy and Inequality

There are limited empirical literature on the implications of unconventional monetary policy on income inequality. However, some studies are conducted on conventional monetary policy. Among the previous literature on the relationship, several authors emphasize the limitations of the income data available. Most papers lean towards an agreement that there is a close connection between monetary policy and inequality, however, whether they find a positive or negative correlation between the two, vary.

Furceri et al. (2016)

Furceri et al. (2016) study the relationship between income inequality and monetary policy, analyzing 32 countries on data from 1990-2013, analyzed through impulse response functions. The yearly income data is derived from Standarized World Income Database. The paper provides evidence that a contractionary shock worsens the distribution, while an expansionary policy reduces income inequality.

Coibion et al. (2012)

"*Innocent Bystanders? Monetary Policy and Inequality in the U.S.*" by Coibion et al. (2012) study conventional monetary policy and the effect on income and consumption inequality in the United States. The empirical research is based on VAR models. The paper examines whether monetary policy has affected income and wealth inequality, by focusing on the five channels: the income distribution channel, the financial segmentation channel, the portfolio channel, the saving redistribution channel and the earnings heterogeneity channel, as outlined in 2.3.3.

The study examines quarterly micro-data from 1980 to 2008, using income and consumption numbers from the Consumer Expenditure Survey (CEX) conducted by the Bureau of Labor Statistics. The study by Coibion et al. (2012) has some noteworthy drawbacks. The CEX does not provide data on the top one percent of the income distribution. Additionally, the paper only focuses on conventional

monetary policy and disregard the following period of unconventional monetary policy.

In particular, Coibion et al. (2012) provide evidence that the effect of monetary policy on income inequality is larger when the interest rate reach the ZLB. The paper concludes that a contractionary monetary policy shock will increase income, labor earnings, consumption and expenditure inequality in the long run.

Davtyan (2016*a*)

Further explanations are provided by Davtyan (2016*a*) in the paper *"The Distributive effect of conventional and unconventional monetary policies"* and in the paper *"Income Inequality and Monetary Policy: An Analysis on the Long Run Relation"* (Davtyan 2016*b*). By the use of a structural VAR model, *"The Distributive effect of conventional and unconventional monetary policies"* analyzes the impact of conventional and unconventional monetary policy instruments on income distribution in the United States over the time period from 1983 to 2013. The paper attempts to provide a solution to the yearly data limitation of the Gini coefficient by interpolating the Gini coefficient into a higher frequency measure. Additionally, the paper presents the 50-10 ratio and the 90-50 ratio, using income data from the Current Population Survey.

In the specification of the VAR model, Davtyan (2016*a*) sets the ordering Real GDP, GDP deflator, Gini, Federal Funds rate. The paper concludes that the Gini coefficient decrease with 0.1 percentage points as a consequence of a contractionary monetary policy shock.

"Income Inequality and Monetary Policy: An Analysis on the Long Run Relation" by (Davtyan 2016*b*), studies the time period 1983 to 2012 and uses a VAR and vector error correction model (VECM) to analyze the effects of monetary policy on income inequality. The research provides evidence that tightening monetary shocks reduces the Gini coefficient and that there is a long run relation between monetary policy and inequality.

5.2 Unconventional Monetary Policy and Inequality

Davtyan (2016*a*)

Davtyan (2016*a*) also analyzes the scenario of unconventional monetary policy using interpolated monthly data. The Federal Reserve's total assets and monetary base are used as measurement for the unconventional monetary policy stance. In this estimation, the variables are ordered with real GDP first, followed by the GDP deflator, the Federal Reserve total assets and the Gini coefficient last in the order.

In the unconventional monetary policy model, the paper presents evidence that the Gini coefficient increases with 0.07 percentage points as a result of an expansionary shock. Thus, the paper argues that the distributive effect of monetary policy should be recognized.

Saiki & Frost (2014)

This is supported by Saiki & Frost (2014) who study the relationship between unconventional monetary policy and inequality in *"How Does Unconventional Monetary Policy Affect Inequality? Evidence from Japan"*. The authors base their analysis on the case of Japan between 2002 to 2006 and 2008 to 2013. Japan carried out a quantitative easing program in 2001 after a period of zero interest rate policy from 1991 to 2000, and later, new rounds of unconventional instruments after the financial crisis of 2007-2008. Aggregated data from the Household Survey conducted by Japanese Cabinet Office is employed as a source of income data to calculate the Gini coefficient. The paper also estimate VAR models with variables on a quarterly frequency.

The paper assumes that the central bank reacts to output and inflation, and contributes the monetary stimulus to a reaction to changes in these variables. In other words, they state that monetary policy contemporaneously reacts to output and inflation. They further assume that the stock market (proxied by the Nikkei index) is influenced by the previously mentioned variables, and that stock prices finally

contemporaneously effect distribution of income. This ordering indicates an assumption that the stock market is the primary channel in which monetary policy affects income inequality. The ordering of the variables is consequently; GDP, inflation, monetary policy stance, stock prices and the Gini coefficient. Finally, Saiki & Frost (2014) find a positive relationship between unconventional monetary policies and income inequality. Furthermore, the paper raises a concern for similar or larger side effects in countries where a larger share of households' savings are placed in bonds and equities.

Domanski et al. (2016)

Domanski et al. (2016) analyze the relationship between monetary policy and wealth inequality, by using a simulation exercise, observing the data at a single-point in time. The paper focus on wealth effects within advanced economies and its underlying monetary policy drivers. The paper draws upon unconventional monetary policy across countries, using household survey as source for wealth data. A limitation to the paper is the exclusion of the top percentiles of the population [11], and the reliability of the wealth data used across countries is questioned in the paper.

The analysis demonstrates that wealth inequality measured by wealth distribution across percentiles has risen since the financial crisis. According to the paper, the main explanation is through rising equity prices.

O'Farrell et al. (2016)

O'Farrell et al. (2016) investigate the relationship between monetary policy and inequality for several countries by using a simulation, with the Gini coefficient and ratios of income quintiles as a measure of income inequality. According to their paper, increases of house prices will reduce inequality, while a rise to equity and bond prices increase inequality. However, the authors argue that the effects on inequality in wealth and income of monetary policy are complex. O'Farrell et al. (2016) focus on the financial channels and underline cross-country differences.

[11] This limitation is in general typically underrepresented in household surveys

Watkins (2014)

Watkins (2014) discusses quantitative easing and its contribution to inequality in wealth and income. He finds that quantitative easing has failed as an instrument to reduce unemployment in the United States. The paper is based on the Survey of Consumer Finances and the CEX and discusses the fairness of the quantitative easing program completed after the financial crisis comparing the distribution across income quintiles. Watkins (2014) argues that the upper income bracket has increased their share of total wealth and supports the findings of O'Farrell et al. (2016).

Final Remarks

After surveying the literature there is a wide range of methods, variables, assumptions and time frames in the study of the distributive impact. As a result, the conclusions drawn are varying. However, a common denominator is the use of VAR models to analyze the effects of monetary policy shocks.

Previous research has applied different approaches to deal with limitations in income data. For instance, Davtyan (2016*a*) chose to solve the low-frequency Gini problem by interpolating yearly data on Gini coefficient to get quarterly Gini estimates. Most papers base their income inequality measures on survey data, despite that the data source is limited towards the upper tail of the income distribution. In general, there are drawbacks related to the different data sources and methods applied in which we defer to discuss until the next section.

Additionally, the papers vary in regard to choices of proxies for monetary policy during the ZLB. Most previous literature on unconventional monetary policy apply monetary base or total assets of the Federal Reserve. Using the latter as measure mainly accounts for the quantitative easing part of the unconventional monetary policy, when the Federal Reserves acquired assets during the various quantitative easing programs. Consequently, this measure neglects the forward guidance instrument. Several papers also encounter the problem of measuring monetary policy in a sample that ranges from conventional to unconventional monetary policy periods.

This limitation makes comparisons between the two periods difficult. To our best knowledge, no study on the relation between monetary policy and income inequality uses the Shadow Federal Funds rate as estimate of unconventional monetary policy. This rate was introduced as a solution to this challenge.

Further, Saiki & Frost (2014) include the Nikkei Index in order to explain the relationship between monetary policy, financial market and inequality. However, due to the difficulties of testing the different channels, there is limited literature empirically testing the channels of income inequality.

Despite some contradicting and ambiguous results, a large share of the previous findings provide evidence that income and wealth inequality is sensitive to monetary policy decisions. As the policy was first implemented in the United States and some European countries after the financial crisis, previous research is scarce. Prior literature request further research on the distributive effects of the unconventional policy instruments.

This paper attempts to fill some of the research gap by estimating a quarterly Gini and income ratios based on household survey data, as a way to solve the low frequency issue on income inequality measures. Furthermore, using the Shadow Federal Funds rate as a proxy for the monetary policy stance, we aim to include forward guidance in our empirical research. Theory suggests that there are five main channels which monetary policy transmits into income inequality and this paper highlights and empirically test some of these channels.

6 Model

In the following section, the theory behind the applied econometric model will be outlined as well as the chosen identification scheme. Further, two methods of interpreting VAR is outlined, namely the impulse response function and variance decomposition. Then follows a detailed account of the variables employed in the empirical models and the sources where the variables are extracted. Finally, the potential drawbacks of the estimation method and data sources will be discussed.

6.1 Vector Autoregressive Model

The empirical analysis relies on VAR models. A VAR is a multivariate linear model where a variable is explained by its own lagged values as well as the past and current values of the other variables. The same is true for all variables. In comparison, a univariate model (AR model) is a model consisting of one variable exclusively. In this version, the current value of a variable is explained by the lagged values of the same variable. A VAR model is consequently an extension to the univariate autoregressive model and used to analyze the dynamics of variables in multiple time series. The model has been recognized as an efficient tool within forecasting and policy evaluation. Within the studies of monetary policy, it has become a common approach to analyze the impact of monetary policy decisions. The VAR model approach was developed as a macro-econometric framework in the 1980's and designed to replace a variety of approaches to data description, forecasting, structural inference and policy analysis (Stock & Watson 2001).

Equation 4 presents a VAR(p), i.e. a model of order p. The left side of the equation shows a vector with k equations (where k is equal to the number of endogenous variables), with a (k x 1) dimension. The other side of the equation shows a (k x 1) vector of constants, followed by a (k x k) coefficient matrix interacted with the endogenous variables, y_t, denoted by the time term and number of lags in the model.

Finally, a (k x 1) dimensional innovation process, v_t.

$$y_t = \phi_0 + \phi_1 y_{t-1} + ... + \phi_p y_{t-p} + v_t \tag{4}$$

y_t - vector of endogenous variables

ϕ_0 - vector of constants

ϕ_i - coefficient matrices

p - order of VAR, also known as lags

v_t - vector of error terms, assumed to be white noise [12]

Three main versions of a VAR model exist: the reduced form, the recursive form and the structural form. The reduced form of the VAR model includes the past values of all variables and an error term that is uncorrelated across time. In comparison, in a recursive VAR model the error terms are uncorrelated with error terms in the preceding equations (Stock & Watson 2001). Finally, a structural VAR model is used for modelling the causal relationship between different variables and is based on the ideas of Sims (1980). A structural VAR analyzes the structure of the economy and applies additional features to the VAR model explained above (Stock & Watson 2003).

The structural VAR model was introduced by Sims (1981, 1986), Bernanke (1986) and Shapiro and Watson (1988). Rather than focusing on identifying the autoregressive coefficients, the structural VAR model evaluates the system errors. In the model, the errors of the system represent the linear combinations of exogenous shocks (Lütkepohl & Krätzig 2004). The structural VAR can be presented as:

$$AY_t = B_0 + B_1 Y_{t-1} + ... + B_p Y_{t-p} + \varepsilon_t, \quad \varepsilon_t \sim N(0, I) \tag{5}$$

Where I is the identity matrix and A is a (k x k) matrix.

The errors of the structural VAR (often called structural shocks) are uncorrelated.

[12] The error terms are assumed to have an expected value of zero ($E(v_t)$=0), a (k x k) positive-semidefinite covariance matrix, i.e. the error terms can be correlated across equations ($\mathrm{E}(v_t v_t\prime) = \Sigma_v$) and serially uncorrelated, i.e. uncorrelated across time ($\mathrm{E}(v_t v_s\prime)$=0) (Hatemi-J 2004).

However, theoretically the structural VAR cannot be estimated directly, in contrast to its counterpart, the reduced-form VAR. Multiplying *equation 5* with the inverse of matrix A, A^{-1}, the reduced-form VAR can be expressed in the following manner:

$$A^{-1}AY_t = A^{-1}B_0 + A^{-1}B_1Y_{t-1} + ... + A^{-1}B_pY_{t-p} + A^{-1}\varepsilon_t, \tag{6}$$

Which, after some notional changes, can be represented as:

$$Y_t = G_0 + G_1Y_{t-1} + ... + G_pY_{t-p} + v_t, \quad v_t \sim N(0, \Sigma_v) \tag{7}$$

Going from *equation 6 to 7*, the A matrix is multiplied with its own inverse, which is equivalent to the identity matrix. The (k x 1) v_t is now the decomposed reduced-VAR error term, that can be expressed as the linear combination of the inverse of A and the underlying structural shocks ε_t:

$$v_\mathrm{t} = A^{-1}\varepsilon_\mathrm{t} \tag{8}$$

The reduced-form error terms might be correlated across equations. Indeed, we want to estimate the effects of structural shocks (the orthogonal shocks) on the Y-vector of endogenous variables. Thus, the structural shocks (ε_t) can be disentangled from the inverse of A (Kilian 2011).

6.1.1 Cholesky Decomposition and Identification

To orthogonalize the shocks, i.e. make the errors uncorrelated, a transformation is required. One such choice of orthogonalization is to apply structure to the variance-covariance matrix of the error term. This paper applies the Cholesky decomposition to the models. The transformation allows the variables to be shocked, whilst keeping the other variables fixed. In this manner, we add economic meaning to the policy analysis and impose a recursive ordering of the shocks.

In this paper, the ordering of the variables is set manually, by the use of economic theory in regards to the extent that the variables are assumed to react in relation to each other. In other words, the ordering is arbitrary and the use of the ordering is consequently only appropriate if the ordering can be "justified on economic grounds" (Kilian 2011, p. 5). The variables ordered first are assumed to react to later ones with a lag. Potential exogenous variables will thus be ordered first. The variables ordered last are assumed to be affected by the former variables contemporaneously. In other words, the variables ordered earlier are allowed a contemporaneous effect on the other variables, whilst the opposite is not true.

This can be shown more technically as following. Substituting ε_t, into the variance-covariance of the reduced-form error term, v_t, which could be written as *equation 8*, we obtain

$$E(v_t v_t') = A^{-1} E(\varepsilon_t \varepsilon_t') A^{-1\prime} \tag{9}$$

$$\Sigma_v = A^{-1} \Sigma_\varepsilon A^{-1\prime} \tag{10}$$

Further, assuming the variance-covariance matrix of ε_t is identity, i.e. $\Sigma_\varepsilon = I$, we get the following

$$\Sigma_v = A^{-1} I (A)^{-1\prime} \tag{11}$$

The Cholesky decomposition requires a lower-triangular (k x k) matrix, P (the Cholesky factor), that satisfies the condition:

$$\Sigma_v = PP' \tag{12}$$

The P matrix should be determined so the variance-covariance matrix of v_t, Σ_v, have variances on the diagonal, and zeros on the off-diagonal (i.e. uncorrelated error terms). A^{-1} is one possible solution to this (Kilian 2011). The restrictions imposed on the A matrix set the instantaneous relations between the variables, where number of restrictions need to satisfy $K(K-1)/2$ for just identification (Kilian 2011).

6.1.2 Applying the VAR Model

Applying the preceding theory to our four-variable baseline model, we can represent the decomposed reduced error-terms in the same manner as in *equation 8*. The main variables of interest are: real GDP growth (y_t), inflation rate (π_t), an income inequality measure (G_t) and a monetary policy indicator (MP_t). In our models, innovations to the monetary policy indicator will give the measure of changes to monetary policy. Given the vector of endogenous variables, $Y_t = [y_t, \pi_t, G_t, MP_t]$, the A^{-1} is equivalent to the lower triangular matrix in *equation 13*:

$$\begin{bmatrix} v_y \\ v_\pi \\ v_G \\ v_{MP} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{12} & a_{22} & 0 & 0 \\ a_{13} & a_{23} & a_{33} & 0 \\ a_{14} & a_{24} & a_{34} & a_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_y \\ \varepsilon_p \\ \varepsilon_G \\ \varepsilon_{MP} \end{bmatrix} \tag{13}$$

With $K = 4$, the matrix is set by 6 restrictions and is consequently exactly identified. In our model the Cholesky ordering will translate to: the macroeconomic variables ordered prior to the monetary policy measure. Output and inflation are some of the key determinants in the policy making of the Federal Reserve. The central bank reacts to changes in these, and we assume no instantaneously relation from monetary shocks to the two[13] (Sims 1980). Both are recognized to be sticky and consequently respond with lag to a monetary policy shock. Further, the ordering state that inflation responds contemporaneously to changes in GDP. The variable ordered before the monetary policy measure gives an indication of the relation in which the monetary policy induces on income inequality. The income inequality measure is assumed to be a persistent variable. We assume that when the Federal Reserve sets its policy, wages will not be affected immediately, rather with a delay, placing the policy variable last in the order.

In a VAR model, the effects of innovations to a variable (in our case: monetary policy innovations) are traced out by impulse response functions (IRF) or forecast

[13]Common practice in closed economies (Bjørnland & Leitemo 2009).

error variance decomposition (FEVD).

6.1.3 Impulse Response Function

IRFs show the response of a shock to different endogenous variables, either on the variable itself or any of the others, to a change to the current value of a VAR error. The underlying assumption is that the error restores to zero in following periods and that the other errors are constant at zero (Stock & Watson 2001). This assumption is adequate if the shocks of the variables can be considered to be independent of each other. If this is not true, the IRFs will yield misleading indications (Lütkepohl 2005). In the previous subsections we demonstrated how these errors can be decomposed to become uncorrelated. When using Cholesky ordering, the orthogonalized IRFs are used in order to analyze the structural shocks. The ordering of the variables in the model will consequently have a considerable impact to how the orthogonalized IRFs will evolve.

6.1.4 Variance Decomposition

In addition to IRF, another informative interpretation analysis of VAR models is the forecast error variance decomposition (FEVD). The decomposition provides the contribution of the different variables to the variance of each of the variables (Lütkepohl 2005). This provides an indication as to which variables account for most of the variation in the others (Brandt & Williams 2007). The variations may be explained by either the past value of the variable itself, or by the past values of the other variables in the system (Brandt & Williams 2007).

For the intention of this paper, the contribution of income inequality to an innovation of the monetary policy indicator, will be of highest interest.

6.1.5 Lag Order Selection

Variables are often correlated with its own past values, i.e. serially correlated. To eliminate this autocorrelation, selecting the relevant lag order is necessary. The selection is a trade-off between the marginal gains from adding more lags, that might contain important information of the past values, and the costs of using excessive lags, which may create estimation uncertainty (Stock & Watson 2003).

To determine the order, p, of the VAR models, the most common determinants used are Akaike information criterion (AIC), Bayes information criterion (BIC), and the Hannan-Quinn (HQC) (Zivot & Wang 2006). Of the estimates these provide, the smallest estimate suggests the lag order that is best fitted to the data. We will take these into considerations when determining lag order in the VAR models in the next sections.

6.2 Data and Variables

6.2.1 Real Economy

To get estimates of the stance of the real economy, data on real Gross Domestic Product (GDP) is included. The real GDP measures the value of services and goods within United States that is produced by labor and property, adjusted for inflation (Federal Reserve Bank of St. Louis 2017). The real GDP has been steadily increasing over the last years, with a downfall in the aftermath of the financial crisis. In general, GDP is observed to grow approximately exponential, hence the variable has been transformed to its logarithmic version and transformed to growth rate by taking the first difference (Stock & Watson 2003).

Data

The data is provided by the Bureau of Economic Analysis and retrieved from FRED, with chain-prices, seasonally adjusted, and is extracted on a quarterly basis.

6.2.2 Inflation

In line with common practice when measuring monetary policy changes, the price index chosen is less food and energy. Volatile and sudden changes in food and energy do not necessarily paint a realistic picture in forecasting. Both categories are subject to external shocks, to a higher degree than other categories of the price index. Although being important factors for households, eliminating these volatile categories is intended to give a better picture of the underlying price development. Naturally, the Federal Reserve monitors several price indices when evaluating the policy making, however, this chosen core inflation index is often emphasized. The rate is transformed to the logarithmic form. Additionally, as the price index time series are non-stationary, the growth rate is calculated in order ensure stationarity. The variable is thus the first order difference to the logarithm.

Data

Data on inflation is collected from Bureau of Economic Analysis from the U.S. Department of Commerce. The data is based on inflation in domestic personal consumption, and is the chain-priced personal consumption expenditure, adjusted for seasonality (referred to hereafter as inflation) (U.S. Bureau of Economic Analysis 2017).

Price Puzzle

A commonly reported empirical anomalies within research done with VAR models is the unexpected increase of inflation to a contractionary monetary policy shock, first presented by Sims (1992). A comment written by Eichenbaum (1992) to the results of Sims (1992), named it the price puzzle. They explain the contradictory findings by the likelihood that monetary authorities have additional information on the inflation which are not explained in the VAR model. The authorities react on this additional information, and thus increase the interest rate. Therefore, the IRF may indicate that the tightened monetary policy action has actually increased interest rates and inflation, as well as reduced aggregate output. The problem in relation to

the VAR model is that researchers are unable to observe the hypothetical inflation level if the monetary policy authorities had not reacted. (Eichenbaum 1992). This can consequently be viewed as one of the omitting variable biases explained in the drawbacks of the VAR models in previous section.

6.2.3 Gini Coefficient and 90/10 Ratio

As outlined in *section 4*, this paper measures income inequality by calculating the Gini and the 90/10 ratio. The income data, on which these calculations are based, are measured on household level and reported quarterly. The income inequality estimates are therefore also calculated with a quarterly frequency.

Data

The World Bank provides estimates of the Gini. However, the database is limited as to the number of countries reported. For the intention of this paper, the main limitation of this database is related to the frequency as estimates are only published on a yearly basis (World Bank 2017).

To obtain the most accurate responses to income inequality from monetary policy changes, a higher frequency than yearly was desired. In other words, constructing quarterly Gini and 90/10 ratios based on collected data was preferred to the estimates provided by the World Bank. However, when estimating income inequality, several challenges emerges. First, gathering data on the full income distribution is difficult. There are two main sources of this type of data; different surveys at household level and tax returns data (Hoeller et al. 2012).

The first source is household surveys. One of the drawbacks of this sort of data source is related to the data on high-income earners. This group is usually underrepresented in surveys. There are two components of this trend: one is the lack of responses from high-income households in general terms. The other relates to the fact that when the respondents from this group actually do respond, they have a tendency to underestimate their income. However, the presence of under-representation at

the other end of the income ladder is also usually assumed. Consequently, the gap between the poorer and richer tends to be underestimated because of the nature of sampling of populations (Hoeller et al. 2012).

In theory, tax return data should eliminate some of the drawbacks of household surveys. Tax data should contain all recipients of income (those declared in tax returns) and thus circumvent several sampling issues, such as over-/under-representation and biases in responses. However, in practice, issues such as tax evasion is likely to present some biases, although these are not perceived as being as large as for surveys (Hoeller et al. 2012). Piketty (2014) suggests that the level of income within the highest income group could be underestimated if the tax return data fails to include all types of income. However, in general the tax data sources contribute mainly by providing more top income data. Thus, research based on this data source usually report top 1 percent income share or similar.

Both sources have certain limitations, and the variations between the two provide quite different estimates. In the United States during the past few decades, household surveys have tended to give estimates of the income gap which are biased downwards, compared to estimates based on tax data (Burkhauser et al. 2009).

Consumer Expenditure Survey and Estimation

The income data applied in this paper are collected from the comprehensive CEX from the Census Bureau on behalf of Bureau of Labor Statistics (Bureau of Labor Statistics 2017). More specific, the public micro-data from the panel Interview Surveys are used. This data is based on consumption units [14] where each unit is interviewed in regard to their income and expenditures for four consecutive quarters. The Census Bureau contacts 12 000 addresses to conduct the survey, whereas approximately 7 000 of these fulfill the requirements set. Thus, the variables constructed based on this data contain approximately 7 000 times seven years of observations,

[14] Bureau of Labor Statistics (2016*a*, p.37) definition: "*(1) all members of a particular household related by blood, marriage, adoption, or other legal arrangements; (2) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (3) two or more persons living together who use their incomes to make joint expenditure decisions*".

yielding 49 000 observations. In the following, the assumption is made that the sample is a representative measure of the overall household income distribution in the United States.

As outlined in the transmission mechanism in *subsection 2.3.3*, monetary policy is subject to impact inequality through different channels. Labor earnings and financial income are likely to give rise to distributive effects, and influence the households differently, as they are heterogeneously exposed to the two income sources. Consequently, this paper will address two different definitions of income, when measuring the disparity. The first is labor income. The measure used for earnings is defined by [15], the Bureau of Labor Statistics as: *"Amount of wage and salary income, before deductions, received by all CU members in past 12 months"* (Bureau of Labor Statistics 2016*c*, p.17). The data collected for labor earnings are likely to be more accurately registered and consequently a better indicator of the wage-distribution in the population. Indeed, households are likely to have a better overview over this income source than financial income, giving more correct estimates of their earnings (Coibion et al. 2012).

The second income measure is total income, which for the sake of this paper will be defined as the amount of consumer unit income in the past 12 months. As a measure for the broader term of income, we use a variable [16] that is defined as labor earnings (i.e., the measure of previous paragraph) in addition to income from; self-employment, Social Security and Railroad Retirement, Supplemental Security Income, pensions (retirement, survivor, or disability), interest and dividends, royalty, net rental income/loss, public assistance or welfare, value of food stamps, Veterans Administration payments, unemployment compensation, child support, alimony, scholarships or fellowships (Bureau of Labor Statistics 2016*c*, p.16). Both income types are measured before tax deductions. The availability of both labor and total income in the CEX database constitutes as one of the main reasons for this choice of database.

[15]The variable used from CEX is "FSALARYM"
[16]The variable employed is the "FINCBTXM"

Consequently, two Gini coefficient time series will be calculated, as well as the 90/10 ratio for total income. For comparative reasons, *figure 11* shows the authors' estimated Gini coefficient based on both wages and total income. The total income Gini coefficient shows a higher level of income inequality than wages, but both seem to follow the same pattern. Piketty (2014) also finds a similar pattern in his sample ranging from 1970 to 2010 and concludes that the inequality seems to be mostly due to changes in wage inequality.

Figure 11: Estimated Gini Coefficient

Source: Authors own calculations

Another useful source for collecting income data at household level is provided by the CPS, retrieved from the U.S. Census Bureau. The sample size of CPS is considerably bigger than the one of CEX. In order to check whether the Gini coefficient calculated by the authors are consistent with those collected from CPS, the yearly average of the calculated Gini coefficient (with total income) are presented. The dashed line shows the Gini coefficient estimated by CPS. As illustrated in *figure 12*, the estimates seem to be robust to those found in CPS, hence one can expect similar empirical results obtained by using this alternative data source.

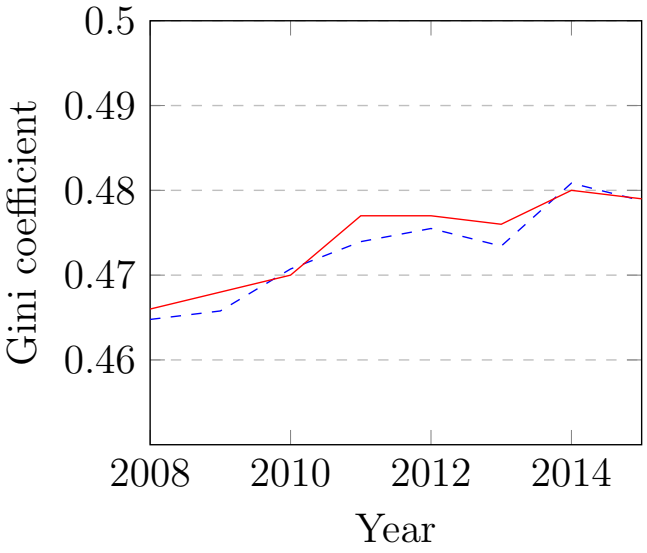


Figure 12: Comparison of Gini Estimates from different Sources

Source: Authors own calculations (red line) and calculations from Proctor et al. (2016) (blue dashed line)

To further confirm the validity of CEX, Sabelhaus et al. (2013), compare the income data to the CPS and the tax-based data from the Statistics of Income from Internal Revenue Service (IRS). The CEX and CPS data follow the shape of the IRS across the income distribution quite consistently. However, they provide evidence that the top household group is underrepresented in both the CPS and the CEX.

6.2.4 Shadow Federal Funds Rate

To measure the stance of unconventional monetary policy, the Shadow rate of Wu & Xia (2016) will be applied[17]. The Shadow rate quantifies the effect of quantitative easing and forward guidance in the United States. Wu & Xia (2016) provide evidence that the Shadow Federal Funds rate can be used to analyze monetary policy effects below the ZLB. In the paper *"Measuring the Macroeconomic impact of Monetary Policy at the Zero-Lower Bound"* they present a non-linear term structure model which enables assessment of the monetary policy's effectiveness and impact on the economy. Due to the structural break in the Federal Funds rate at the before-

[17]See subsection 3.3 for further details

mentioned bound, estimation of monetary policy in VAR became challenging (Kilian 2011). To cope with this problem, Wu & Xia (2016) have created the possibility of allowing unconventional monetary policy, measured by the Shadow rate, to be a continuation of the Federal Funds rate. Consequently, the policy rate has made the VAR output inference more valid.

Data

The data for the Shadow Federal Funds rate is collected from the Federal Reserve Bank of Atlanta. The bank provides estimates of the Wu-Xia Shadow Federal Funds rate on a monthly basis. When the target Federal Funds rate is above or equal to 0.25 percent, the Shadow rate is not updated. In the United States, the Shadow Federal Funds rate has yet only been applicable for the period between 2009 and to the beginning of 2016. The data range of the Shadow Federal Funds rate is therefore based on the period from 01/2009-11/2015 (The Federal Reserve Bank of Atlanta 2016) as illustrated by the green line in *figure 4* in *section 3.3*.

6.2.5 Federal Funds Rate

To measure the monetary policy stance during conventional times, the variable employed is the effective federal funds rate. Admittedly, the stance of the policy during normal times might not be explicitly reflected through this rate. Consequently, the Federal Funds rate (FFR) is chosen over other measurements of conventional monetary policy. Alternative measures are non-borrowed reserves, as suggested by Eichenbaum & Evans (1993) and Strongin (1995). The use of this rate is justified based on its relation to the Shadow Federal Reserve rate. As this paper will investigate conventional monetary policy on the premise of comparing its effect to the unconventional counterpart, using a comparable measure seems evident. Additionally, Bernanke & Blinder (1992) find the interest rate as policy instrument to be the most informative.

Data

The rates are collected from the Board of Governors of the Federal Reserve System (US), collected from the Fred database (Federal Reserve of St. Louis 2017).

6.2.6 Earnings

Financial markets, and consequently asset prices, react immediately to monetary policy announcements. The financial markets are consequently used as channel for the central bank to alter people's behavior. Bernanke & Kuttner (2005) find that an unexpected drop in the Federal Funds rate of 25 basis points increases stock markets by 1 percent.

Including the high frequency stock prices as a variable in the VAR, the estimation faces a simultaneity problem in relation to the monetary policy indicator (Bjørnland & Leitemo 2009). Stock markets react immediately to changes to monetary policy. However, with quarterly data, using for instance the S&P500 as proxy for the stock market and ordering it right after the Shadow rate, would in our model imply that the monetary policy change has an "immediate" effect on stock market. In this case, this would yield the unlikely assumption that this immediate effect is within a quarter, not on daily basis (Stock & Watson 2001). This paper attempts to circumvent this restriction problem by using earnings for S&P500. Earnings will per definition react to monetary policy with a quarterly lag, and will thus be better fitted to our VAR estimation. The earnings variable is chosen over a similar variable, dividends, because earnings experience less erratic seasonal trends (Galí & Gambetti 2015).

Data

To get an estimate of the stock market, numbers based on a United States stock market index, the S&P500, are used. The numbers collected are earnings, reported in real terms, collected from the website of Robert Shiller (Shiller 2017).

6.2.7 Employment Rate

The unemployment rate is an important component of the unconventional monetary policy and income inequality debate. In *section 7.3.2* this will be further tested. However, there are some potential practical challenges connected to the use of the unemployment in policy evaluations in VAR models. First, the unemployment rate is assumed to react to monetary policy with a considerable delay. Bernanke & Blinder (1992) report a period lag of 9 months. Additionally, unemployment is a less observable measure than other labor market indicators.

The employment-to-population ratio is assumed to be a more observable variable. We expect that the variable reacts quicker than the unemployment rate to a monetary policy action. Additionally, the variable consists of a larger sample of individuals. Hence the variable faces less risk of statistical errors (Leon 1981). We will thus use this employment rate as an attempt to circumvent the limitations of the unemployment rate.

Data

The employment rate is collected from U.S. Bureau of Labor Statistics and derived by FRED, Federal Reserve of St. Louis. The variable is the seasonally adjusted Civilian Employment to Population Ratio (FRED 2017) based on Current Population Survey. The ratio describes the percentage of the total population (of working age) that are employed.

6.3 Descriptive Statistics

Finally, a summary of descriptive statistics for the mentioned variables can be found in *table 2*. The variables are reported in their original form, before any potential transformations are conducted. During the unconventional monetary policy period, 2009 to 2015, the statistics are:

Variable	Units	Min.	Mean	Max.	Std. dev.	Transf.
GDP	Billion USD	14 355.6	15 339.8	16 490.7	664.9	Log-diff
Inflation	Index [18]	101.2	106.8	112.7	3.5	Log-diff
Gini (income)	Ratio [19]	45.9	47.4	48.7	0.6	-
Gini (wages)	Ratio	43.4	45.4	46.3	0.6	-
90/10	Ratio	31.2	35.7	43.2	2.9	Log
Shadow	%	-2.89	-1.26	0.25	0.87	-
Earnings	USD	8.3	80.6	107.7	30	Log
Employment	%	58.3	58.8	59.8	0.42	-

Table 2: Descriptive Statistics, 2008 - 2015

"Log" = Logarithm, "Diff" = First difference, "Log-Diff" - First difference of the logarithm, "-" = No transformation

For the conventional period, 1996 to 2008, the relevant statistics are:

Variable	Units	Min.	Mean	Max.	Std. dev.	Transf.
GDP	Billion USD	10 348.7	12 995	14 991.8	1 401.4	Log-diff
Inflation	Index [20]	100.5	111.7	125.3	7.4	Log-diff
Gini (income)	Ratio [21]	46.7	48.5	51.3	0.9	-
FFR	%	0.99	4	6.63	1.87	-

Table 3: Descriptive Statistics, 1996 - 2008

"Log" = Logarithm, "Diff" = First difference, "Log-Diff" - First difference of the logarithm, "-" = No transformation

[18] Indexed to 2008

[19] the Gini Index will show the coefficient as a value from 1-100, which is in line with the World Bank (2017)

[20] Indexed to 1996

[21] Ratio between 0 and 100

6.4 Limitations of Data and Estimation Method

6.4.1 Data Limitations

In relation to measuring a proxy for income inequality, there are several potential drawbacks. As identified in the above sections, the increasing trend in income disparity is especially attributed to changes in the high end of the income ladder. Thus, with data based on household surveys, which are known for their under-coverage of high-income household, the estimated income inequality is subject to be skewed. Missing data on the top section of households might also contaminate our results, as the data on income also have some additional shortcomings. The sample period also represents another drawback of the data. Due to unconventional monetary policy being an unprecedented policy instrument in the United States, the period of analysis is relatively short and limited to the period of 2009-2015. Given that the income data is reported on a quarterly basis, all variables are collected on this frequency. Thus, the number of observations are a limitation, and a bigger sample would ideally have been preferable.

6.4.2 Criticism of VAR models and Estimation

In addition to the potential drawbacks related to the data in our sample, the VAR model also has some limitations. One of these is the possibility of omitted variable bias (Stock & Watson 2001). Our baseline models consist of four variables, and our extended models of five variables. Thus, the possibility of omitting variables that might have had an impact on the output is obviously present. However, VAR models are assumed to be best fitted as low-dimensional, given the limitations of the degrees-of-freedom problem (Bernanke et al. 2004). Consequently, these potentially omitted variables are collected by the innovations. If these variables are correlated with the variables in the model, it will lead to distortions in the interpretations of the impulse responses (Rossi 2010).

The central bank adjusts monetary policy to a variety of economic indicators. Assuming that the Shadow Federal Funds rate in our model is exclusively contemporaneously affected by GDP and inflation, is likely to contaminate our results. A possible solution to this problem would be to estimate a factor augmented VAR (FAVAR) model, which might comprehend larger datasets and several variables to explain the stance of the economy (Kilian 2011). However, this is outside the scope of this thesis and is suggested for further research.

The inference of the VAR model is highly dependent on the ordering of the variables. However, given the endogeneity of policy decisions, researchers disagree on the causal effects, contributing to different ordering of variables. We try to meet this limitation by stating all our assumptions to the dynamics of the macroeconomic variables and by conducting robustness checks with different orderings.

Another limitation relates to the issue of data availability and restrictions in the VAR. Given the quarterly frequency of the variables, the restrictions imposed in the VAR might not always be plausible. One example of this is the variable used to proxy the stock market, the real earnings for S&P500.

7 Empirical Results and Analysis

In the following section, we examine empirically whether monetary policy innovations can explain the variations in income inequality. We employ the baseline specification to both the unconventional and conventional policy regimes. Within the unconventional model, we test for different measures of income inequality. We also investigate whether there are any heterogeneous effects to the different parts of the income distribution. Furthermore, we estimate extended versions of the baseline model which includes stock and labor market indicators. The focus is directed towards three channels which the theory implies would work in different directions to the income gap. To test the sensitivity of our data, the section includes presentations of the conducted robustness tests.

7.1 Baseline Model - Unconventional Monetary Policy

Estimation of the baseline model is set to address the overall effect of monetary policy on income inequality, before considering extensions or variations to the model. The baseline is a four variable VAR model, and includes the variables: real GDP growth rate (y_t), inflation rate (π_t), Gini index (G_t) and Shadow Federal Funds rate ($MP_{Shadow,t}$).

The baseline model is estimated with an order of two lags, i.e. a VAR(2). AIC suggested one lag (and marginally higher for two lags). However, we decided to use two lags since a higher lag order is more likely to eliminate autocorrelation in VAR models (Stock & Watson 2003).

The ordering of the variables is in line with the Cholesky decomposition and expressed in the *vector of endogenous variables 14*.

$$Y_t = [y_t, \pi_t, G_t, MP_{Shadow,t}] \tag{14}$$

The decomposition is applied to identify exogenous innovations to the Shadow Federal Funds rate, i.e. the monetary policy shock. The ordering of the variables are determined according to our assumptions regarding the pace and dynamics of the economy. The macroeconomic non-policy variables are ordered prior to the income inequality and the monetary policy measure.

Further, the ordering reflects the assumption that a monetary policy shock will impact the Gini index with a lag. Wage contracts are agreed upon or renegotiated at a low frequency. Consequently, monetary policy shocks influence wages and potentially income inequality with some delay. At the same time the income disparity measure might contemporaneously affect monetary policy, placing the Shadow Federal Funds rate last.

The orthogonalized IRF of the models are reported for the subsequent 12 periods (in our case one period is equivalent to a quarter). The responses of the variables have been normalized to a 1 percent change of the monetary policy indicator, in order to shock all variables with the same magnitude across models. The dashed lines yield the 95 percent confidence bands.

In the following, different measures of income inequality will be tested in the baseline specification, yielding the models: income inequality model, wage inequality model and 90/10 model.

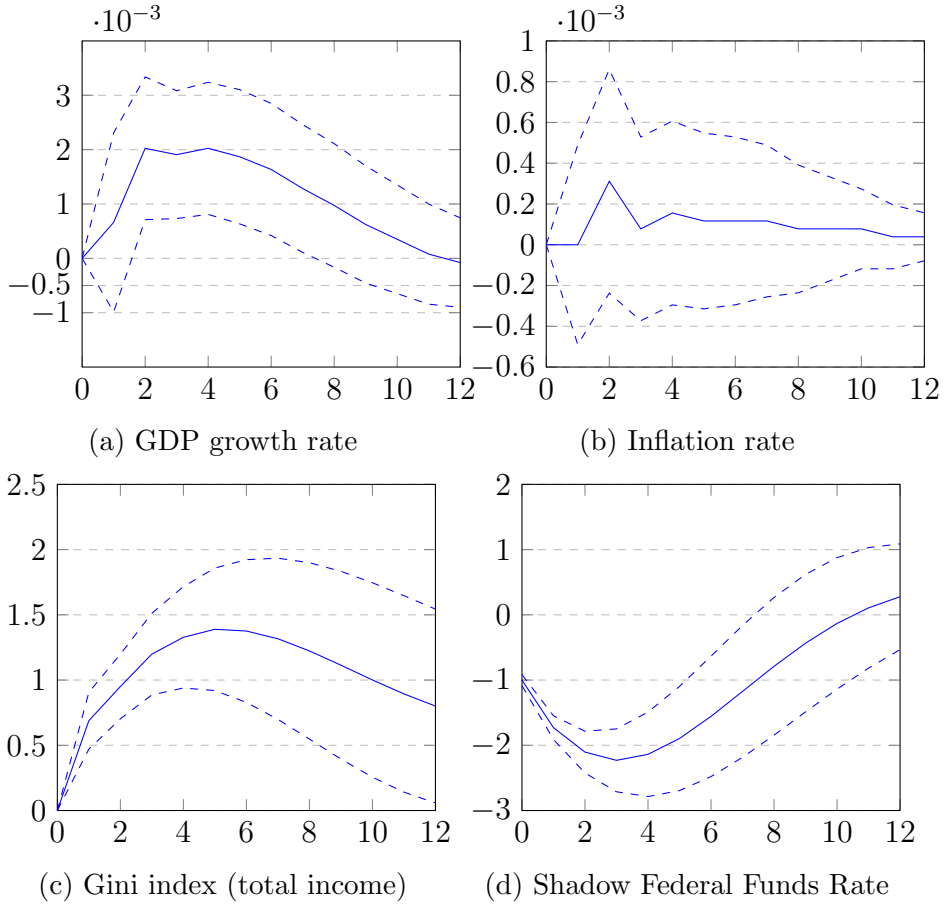
7.1.1 Income Inequality Model

$$Y_t = [y_t, \pi_t, G_{i,t}, MP_{Shadow,t}] \tag{15}$$

With a Gini index based on total income ($G_{i,t}$) as inequality measure, the vector of endogenous variables can be presented as in *equation 15*. *Figure 13* presents the responses of an expansionary monetary policy shock, which in this model translates to an constructed initial drop of 1 percent in the Shadow Federal Funds rate. The effect on the real economy is a small, eventual increase in GDP growth of 0.2 percent at the most after two quarters. The inflation rate also increases slightly after first

quarter. Both variables are evolving in the direction suggested by theory. However, the confidence bands are wide and do not rule out that the opposite can be true for the two variables. The effect on GDP and inflation dies out in the end of the period. [22]

The expansionary shock is in the short-run associated with an increase in income inequality, measured by the Gini index ($G_{i,t}$). The effect reaches a peak after five quarters, with an increase of 1.4 on the Gini scale (given a Gini index going from 0 to 100). The effect on income inequality converges to 0 for the consecutive quarters as the monetary policy shock eventually evaporates. The shock to monetary policy is presented in the lower right panel.



(a) GDP growth rate (b) Inflation rate

(c) Gini index (total income) (d) Shadow Federal Funds Rate

Figure 13: Orthogonalized IRF of Monetary Policy Shock, Baseline (total income)
Ordering: GDP, Inflation, Gini (total income), Shadow rate

[22] In the following, the IRFs of real GDP growth rate and inflation rate will not be reported, as they are not the variables of interest and evolves quite similar for all models.

The results of *figure 13* are in line with the theory of quantitative easing effects on the macroeconomic environment as outlined in *section 2.2.1*. An unconventional monetary policy intervention has a positive effect on GDP growth and increases inflation, which is the same effects as suggested by the transmission mechanism of expansionary conventional stimulus. Furthermore, the result from the upper right panel in *figure 13* does not give any indication of a price puzzle.

In summary, our baseline VAR model indicates that the main variable of interest, the Gini index, increases the quarters following the monetary policy shock. However, to fully comprehend the interaction of the two variables, the relation need to be further exploited.

FEVD - Gini				
Period	**GDP**	**Inflation**	**Gini$_i$**	**Shadow**
1	7.0	24.7	68.3	0.0
2	7.4	20.8	62.8	8.9
3	7.5	17.4	54.9	20.3
4	7.0	14.8	45.4	32.8
5	6.2	13.1	37.9	42.8
6	5.6	11.8	32.2	50.4
7	5.2	11.0	28.2	55.6
8	4.9	10.4	25.6	59.0

Table 4: Forecast Error Variance Decomposition (%), Unconventional Baseline Model

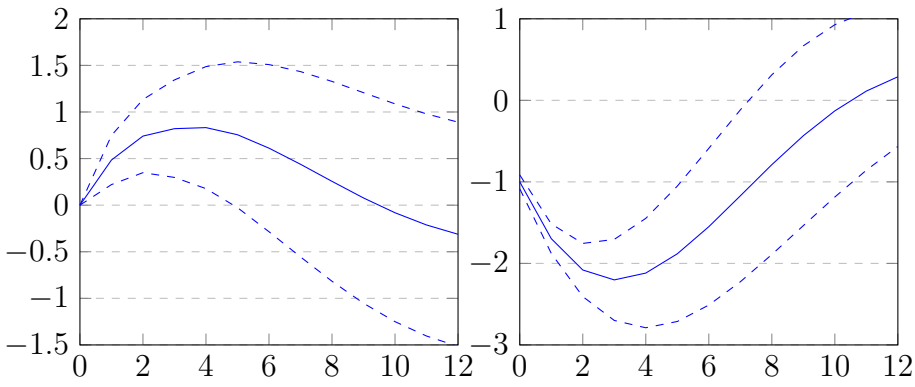
To get an indication of the contribution of the different variables to the changes in the income inequality, we take a closer look at the FEVD. *Table 4* provides the decomposition of the forecast error variances as percentage share. In the first forecasted periods, the variance in the Gini index is mainly explained by its own past values, and by the rate of inflation. After 8 periods (here: quarters) the monetary policy shock is explaining an increasing amount, which at the most accounts for 59 percent of its variation. At this point, approximately 25 percent of the variance can

be explained by the Gini variable itself. GDP accounts for the smallest share of the variance.

7.1.2 Wage Inequality Model

$$Y_t = [y_t, \pi_t, G_{w,t}, MP_{Shadow,t}] \tag{16}$$

To assess the differences in types of income applied in the inequality measure, the Gini index based on wages ($G_{w,t}$) is also reported. The response can be observed in the left panel of *figure 14*. A drop in the Shadow rate of 1 percent increases the Gini index by 0.9 at the most after three quarters. Compared to the IRF of the Gini index on total income, the effect from a monetary policy shock is less pronounced. This confirms the argument that monetary policy is subject to affect the income inequality through other income sources than barely wages, giving support to the income decomposition channel. Hence, in the following models, the income inequality measure will be based on the total income.



(a) Gini index (wages) (b) Shadow Federal Funds Rate

Figure 14: Orthogonalized IRF of Monetary Policy Shock, Baseline (wages)
Ordering: GDP, Inflation, Gini (wages), Shadow rate

Table 5 plots the decomposition of the variance for the Gini index of wages. After 8 quarters, the Shadow Federal Funds rate explains 10.5 percent of the variance in the Gini index and approximately 75 percent is explained by the variable itself. In comparison, the monetary policy innovation seems to account for a smaller portion

of the variance of the Gini index based on wages than the Gini index on total income.

FEVD - Gini				
Period	**GDP**	**Inflation**	**Gini$_w$**	**Shadow**
1	4.7	5.7	89.5	0.0
2	6.8	3.6	87.0	2.7
3	7.1	5.9	80.6	2.6
4	5.7	8.1	77.0	9.0
5	5.2	8.8	75.2	10.8
6	4.8	9.5	74.2	11.2
7	4.5	9.9	74.2	11.3
8	4.3	10.1	75.0	10.5

Table 5: Forecast Error Variance Decomposition (%), Unconventional Baseline Model, Wages

The Gini variable is a commonly applied indicator of the total income inequality stance, and a natural starting point for the analysis. However, further measures should also be investigated in order to confirm that the results are consistent, unconditional of the choice of inequality measure.

7.1.3 90/10 Model

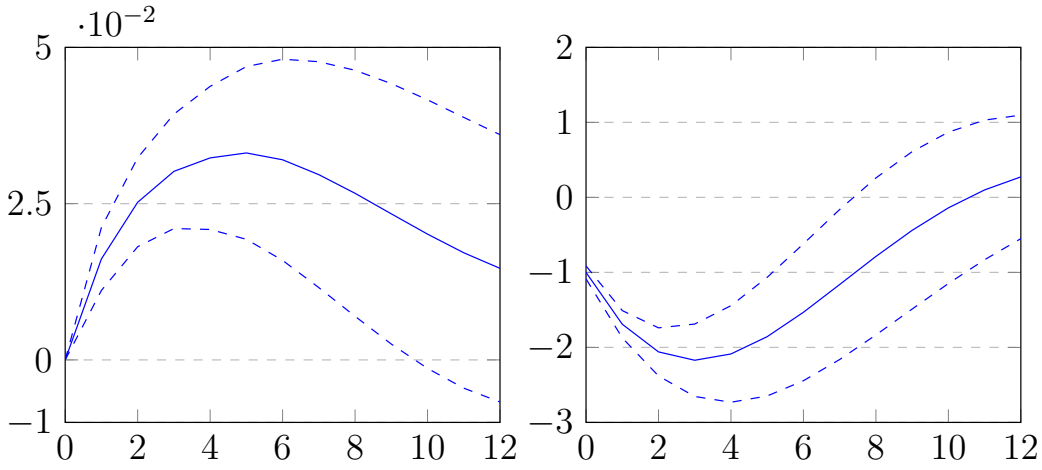
$$Y_t = [y_t, \pi_t, 90/10_{i,t}, MP_{Shadow,t}] \tag{17}$$

The Gini index may have some drawbacks as to the information that it provides, one of them being its sensitivity to the income in middle class [23]. Therefore, we estimate a model using the logarithmic average 90/10 ratio ($90/10_{i,t}$) as measure of inequality. The ratio is applied as it is more sensitive to the upper and lower tail of the income distribution. The ordering of the VAR is consistent to that of the previous models.

[23] As outlined in *section 2.3.2*

Figure 15 provides the responses to the 90/10 ratio, which tracks the same upward trend as the Gini index following a monetary easing. A drop in the Shadow Federal Funds rate of 1 percent increases the 90/10 ratio by 0.03 percent on the ratio, at the highest peak. Then the gap starts to tighten, however, this occurs at the point when the shock of the Shadow Federal Funds rate dies out, as illustrated in the right panel of the figure. The baseline model is therefore robust to different measures of income disparity.

Nevertheless, our findings in *figure 13*, *figure 14* and *figure 15* indicate that the policy may stimulate an enhanced distributional disparity.



(a) 90/10 ratio (total income) (b) Shadow Federal Funds Rate

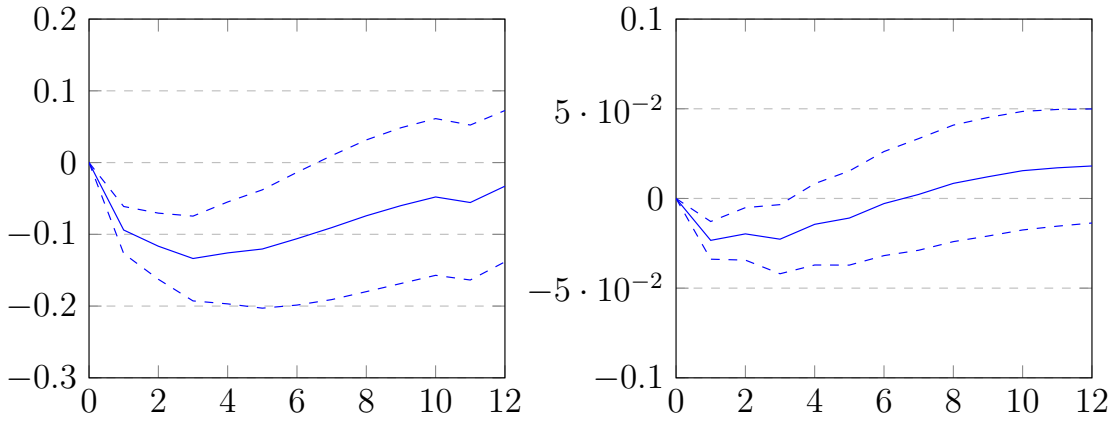
Figure 15: Orthogonalized IRF of Monetary Policy Shock, Baseline (90/10)
Ordering: GDP, Inflation, 90/10, Shadow rate

7.1.4 Heterogeneous Effects on Income Distribution

According to a OECD (2016) report, the effects of the financial crisis and economic recovery have not been distributed equally across households. From the financial crisis of 2007 to 2010 the lowest 10 percent income earners had their income decreased by 9.8 percent while the top 10 percent earners had their income decreased by 3.1 percent. In comparison, during the economic recovery of 2010 to 2014, the lowest decile's income rose by 0.4 percent while the income growth of the highest decile was 8.3 percent. In other words, the financial distress seems to have hit the

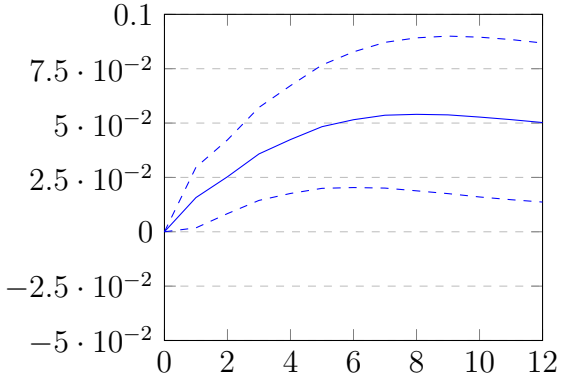
lowest income bracket considerably harder than the highest income bracket. During the economic recovery, both income groups saw their income rise, however, the top income earners benefited the most. Over the period as a whole, the cumulative decrease for the lower income group was 3.2 percent, while increasing 4.4 percent for the highest income group.

Analogously, this section decomposes the ratio into the lower decile, the low-to-median households [24] and the upper decile. In this manner, we can examine the reaction of the individual deciles to an accommodative monetary policy shock to capture the underlying factors of the ratio. We take the logarithm of average income for the upper decile, the low to median households and the lower decile.



(a) Lower decile

(b) Low-to-median



(c) Upper decile

Figure 16: Orthogonalized IRF of Monetary Policy Shock across the Income Distribution

[24] Average income of lower 50 percent

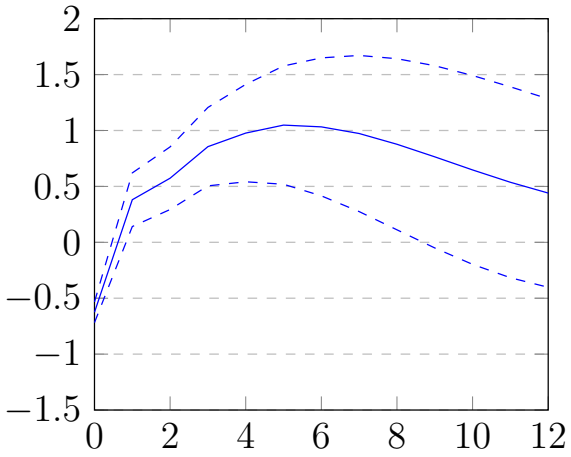
In line with the estimates of the OECD (2016) report, the IRFs of *figure 16* indicate that a drop in the Shadow Federal Funds rate affects households at different deciles disproportionately. The households at the upper decile are indicated to have their income boosted by approximately 0.05 percent after five quarters. This effect persist at the new, increased level throughout the projected period. The opposite effect is suggested for the low-to-median and lower-income households. The low-to-median households' income decrease slightly in the first quarters following the shock of the Shadow rate, then turns insignificant. The lower decile's income decrease by approximately 0.12 percent after three lags. The effect on the lower decile and the low to median households dies out after 12 quarters. However, the direction of the effect is not statistically significant after period six. These findings are also in accordance with Davtyan (2016*b*), who finds that expansionary unconventional monetary policy significantly increases the inequality at the lower part of the income distribution.

7.1.5 Sensitivity Analysis

The models might be sensitive to the choice of ordering. Hence, we perform a robustness test regarding the ordering of the baseline model. Davtyan (2016*a*) and Coibion et al. (2012) order the Gini index and the unconventional monetary policy variable differently than from the baseline model specified above. The alternative ordering puts the Shadow Federal Funds Rate before the Gini index in our model.

$$Y_t = [y_t, \pi_t, MP_{Shadow,t}, G_{i,t}] \tag{18}$$

Consequently, as a robustness check in regards to the ordering of baseline VAR model we estimate the ordering according to these paper. The orthogonalized IRFs then evolve as following:



(a) Robustness

Figure 17: Orthogonalized IRF of Monetary Policy Shock, Baseline (robustness)
Ordering: GDP, Inflation, Shadow rate, Gini (total income))

The effect of a monetary policy shock on the Gini index presents a quite similar response as the baseline model. As the ordering allows the monetary policy to immediately impact the income inequality measure, the IRF reports a change to the Gini index already in period 0. The figure suggests that the Cholesky ordering of the baseline model is fairly robust in regard to an alternative, common ordering of the income inequality measure and the monetary policy indicator.

7.2 Baseline Model - Conventional Monetary Policy

In order to compare the results for unconventional monetary policy to its conventional counterpart, we apply the same baseline specification model to a period where conventional monetary policy was conducted. Given that income data from the CEX before 1996 is not published, we set our sample period from the first quarter of 1996 until the third quarter of 2008.

$$Y_t = [y_t, \pi_t, G_{i,t}, MP_{FFR,t}] \tag{19}$$

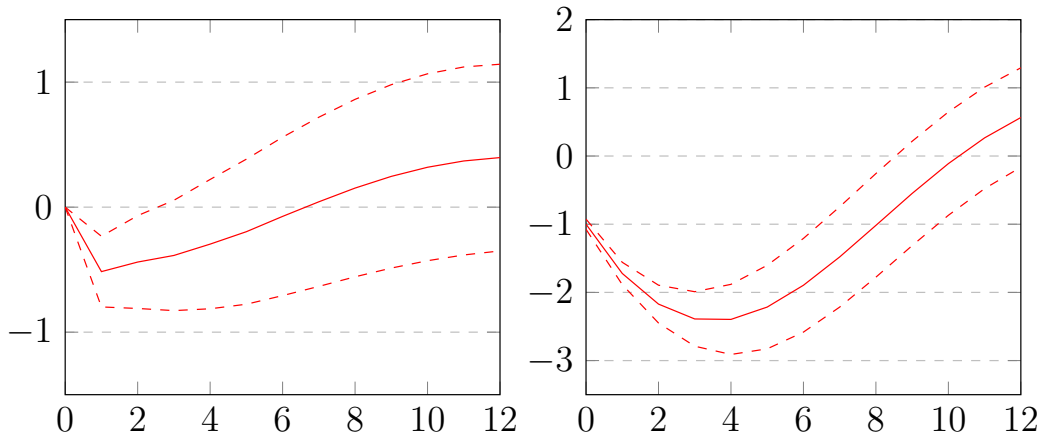
In this version of the model, the Shadow Federal Funds rate is replaced by the effective Federal Funds rate ($MP_{FFR,t}$) as monetary policy indicator. The Federal Funds rate is recognized to be similar to a Taylor-rule formulation, where the central bank reacts systematically to GDP and inflation, which are the determinants of the rate in the Taylor-rule (Keating et al. 2016). The ordering captures this relationship. The other variables are the same as in the unconventional baseline model with a quarterly frequency and ordering as provided in *equation 19*.

In *table 6* the information criterias are presented. BIC and HQC suggest one lag, however, to decrease the possibility of autocorrelation, we decide to use two lags. This is line with the suggestion of the AIC.

Information Criteria	**Lags**		
	1	**2**	**3**
AIC	-892.4	**-893.8**	-872.2
BIC	**-847.2**	-821.8	-774.6
HQC	**-875.6**	-867.6	-836.8

Table 6: Lag Selection by Information Criteria, Conventional Baseline

The IRFs illustrate the impact of a surprise negative innovation to the Federal Funds rate of 1 percent. As presented in the right panel of *figure 18*, the shock gradually dies out after four quarters.



(a) Gini index (total income) (b) Federal Funds Rate

Figure 18: Orthogonalized IRF of Monetary Policy Shock, Baseline (conventional)
Ordering: GDP, Inflation, Gini, Fed Funds rate

The IRFs during the conventional period give an indication that after an expansionary monetary policy shock, the overall income inequality initially decreases after one quarter, and then slowly starts to increase. However, the effects are less persistent and less significant than for the unconventional model. Our results are in line with Coibion et al. (2012), who also find a less significant and pronounced effect on income inequality during conventional times.

The contribution to the variance of the Gini index is reported in *table 7*. As indicated from the IRFs the monetary policy indicator (the FFR) does not seem to explain much of the variations in the income inequality changes. Almost all the variations in the Gini index can be traced by its own lagged values. In comparison with the unconventional case, unconventional monetary policies appear to have a stronger effect on income inequality than conventional policies. In a similar manner, Davtyan (2016*a*) compares the variance decomposition of the two policy regimes, and concludes that unconventional policies have had a more pronounced impact on the Gini index in the United States than its traditional counterpart.

FEVD - Gini				
Period	**GDP**	**Inflation**	**Gini**	**FFR**
1	2.1	2.5	95.4	0.0
2	1.6	1.8	96.3	0.2
3	1.3	1.9	96.6	0.3
4	0.9	2.1	96.6	0.3
5	0.8	2.6	95.9	0.6
6	0.7	3.2	95.2	0.9
7	0.6	3.6	94.5	1.3
8	0.5	4.0	93.8	1.6

Table 7: Forecast Error Variance Decomposition (%), Conventional Baseline

7.3 Extended Models - Unconventional Monetary Policy

Finally, the proposed channels in which monetary policy might affect income disparity will be revisited and investigated in light of the empirical findings from previous subsection. Previous research on the relation has discussed the role of some of the channels, however, limited empirical evidence of the different channels exists. The *financial segmentation channel*, *income composition channel* and the *earnings heterogeneity channel* will be further examined by extensions to the baseline VAR models. First, we investigate the effect of a shock to the Shadow Federal Funds rate on earnings for S&P500. Then we investigate the effects to the employment-to-population ratio. Attention will also be paid to other factors in which monetary policy may have affected income inequality during our sample period.

7.3.1 Stock Market Model

$$Y_t = [y_t, \pi_t, G_{i,t}, S_t, MP_{Shadow,t}] \tag{20}$$

We augment a five variable VAR that includes earnings for the stock index S&P500 (S_t). In same manner as in the baseline model, we assume the macroeconomic vari-

ables, GDP and inflation, to be the slowest moving variables and consequently allow these to have a simultaneous feedback to the monetary policy indicator. We further assume that earnings react with a lag to monetary policy, which in our model translates into a quarterly lag. Developments in the stock market can provide information to the central bank regarding the stance of the economy, which the Federal Reserve might react upon (Kilian 2011). Therefore, earnings is allowed to contemporaneously affect the Shadow Federal Funds rate. The Shadow Federal Funds rate is restricted from having an instantaneous effect on all the other variables. The Gini index is assumed to affect the two latter variables contemporaneously whilst reacting by a lag to monetary policy innovations. The corresponding ortogonalized IRFs are reported below.

The model is estimated as a VAR(3), where the lag order is selected unanimously by all three information criteria, as displayed in *table 8*.

Information Criteria	**Lags**		
	1	**2**	**3**
AIC	-652.7	-673.7	**-747.3**
BIC	-600.9	-591.9	**-637.6**
HQC	-637.3	-650.2	**-716.9**

Table 8: Lag Selection by Information Criteria, Earnings VAR

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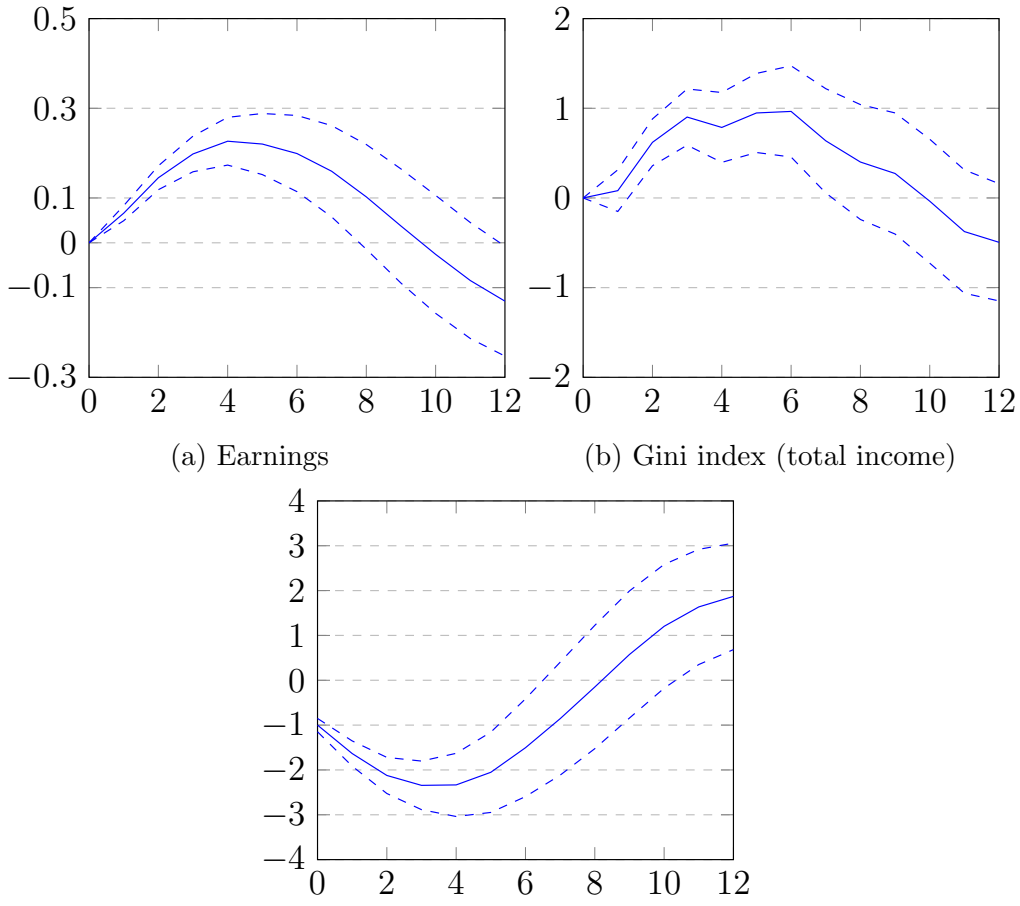
The IRF in *figure 19* an indicate that a surprise expansionary monetary intervention, during unconventional times, will increase earnings in the stock market. This is in line with the theory suggesting that quantitative easing works partly through its effect on the asset market, hereunder the stock market. After the policy shock hits, earnings gradually start rising along with the increase in the Gini index. The Gini index is observed to react in a similar fashion as to the baseline model in *figure 13*. After approximately four quarters, the shock is projected to give an increase in earnings of 0.23 percent at the maximum. After this point, the effect on earnings

and income inequality evaporates simultaneously as the shock perishes.



(a) Earnings

(b) Gini index (total income)

(c) Shadow Federal Funds rate

Figure 19: Orthogonalized IRF of Monetary Policy Shock, Stock Market Model
Ordering: GDP, Inflation, Gini (total income), Earnings, Shadow rate

The *financial segmentation channel* suggests that households that are more connected to the financial markets will be positively affected by increases in equity and asset prices, compared to those not connected. Our results indicate that unconventional monetary policy has increased earnings. This is in accordance with the results of Saiki & Frost (2014) on the case of Japan, which explained that wealth and income inequality rose as a consequence of increased asset prices after the implementation of unconventional monetary policy.

To assess the relevance of the *financial segmentation channel* for our sample, we display how dividends, royalty and income from estates and trust are distributed over

	Bottom decile	Upper decile
2009	0.488 %	43.926 %
2010	0.403 %	49.095 %
2011	0.236 %	41.206 %
2012	0.479 %	33.383 %
2013	0.451 %	37.727 %
2014	0.503 %	40.352 %
2015	0.467 %	42.324 %

Table 9: Financial Income, Bottom versus Upper Decile

our sample based on the CEX. *Table 9* compares the difference between the upper and the lower decile's shares of the financial income of our sample. The table presents the large difference between the income groups. The lower-end only received a share between 0.24-0.50 percent, while the share for the upper-end of the distribution ranged from 33.38 percent to 49.10 percent during the sample period.

The validity of the *income composition channel* is captured in *table 10*. The table displays the source of annual income of households at different quintiles within the United States in 2013 (Congressional Budget Office 2013).

	Lowest	Second	Middle	Fourth	Highest
Average income	**25 400**	**47 400**	**69 700**	**103 700**	**265 000**
Labor	53 %	57 %	63%	69 %	60 %
Business	6%	3 %	2 %	2 %	11 %
Capital	1 %	1 %	2 %	3 %	16 %
Other	2%	5 %	9 %	11 %	8 %
Government transfers	38 %	34 %	24 %	14 %	5 %

Table 10: Income before Tax (USD), in Quintiles, 2013

Source: Congressional Budget Office (2013)

The lower quintile relied almost solely on income realized from labor earnings and

government transfers which accounted for 91 percent of their total income before tax. This quintile only received 1 percent from capital income and gains. In contrast, for the higher quintiles a larger share originated from capital gains and income and business income, accounting for a total of 27 percent of their annual income. Furthermore, the highest quintile only received 5 percent from government transfers.

If a monetary policy action increases financial earnings more than labor earnings, this will not favor all households equally. *Table 10* illustrates that the highest quintile is far more influenced by changes in capital income than the other four quintiles. Consequently, all else equal, through the difference of source of income, the income composition channel increases inequality.

In the period from 2008 to 2012, Cobet (2014) finds that 80 percent of the total rise in income was within the highest income quintile. In contrast, the three lowest quintiles stayed at approximately the same level throughout the period .

In summary, our findings indicate that the stock market has been contributing to income inequality since the implementation of nontraditional policies. Furthermore, the findings from *table 9* and *10* capture the heterogeneous sources of income across the income distribution. However, our results on the S&P500 earnings are not particularly strong in magnitude, with a maximum of 0.23 percent after four quarters. According to Bjørnland & Leitemo (2009), a simple Cholesky identification scheme, as applied in our model, will underestimate monetary policy shock effects on stock prices i.e., suggesting that the effect might be even stronger. Thus, based on our results, it is reasonable to believe that there is a connection between the variables.

Contrary to the results, there are also some arguments that work against this finding, arguing that there are other potential drivers behind the top income increase. Piketty (2014) argues that even though the upper income group has been increasing the last decade, capital gains are not necessarily the main contributor behind this.

He studies the development of the upper decile's income [25] also when excluding capital gains and finds the decile to be growing at a steadily and increasing pace - still at a higher rate than the other deciles.

One could also argue that asset prices have been suppressed during the financial crisis. Consequently, the price increase happening in the aftermath of the crisis may not have been the product of policy stimulus, but rather a price adjustment back to a more normal level.

7.3.2 Labor Market Model

The *earnings heterogeneity channel* implies a transmission of monetary policy through the labor market, more specifically unemployment. As some practical challenges occur when testing unemployment rate in a VAR, we investigate this channel through the employment rate [26].

$$Y_t = [y_t, \pi_t, E_t, G_{i,t}, MP_{Shadow,t}] \tag{21}$$

Maximizing sustainable employment is incorporated in the objective of the Federal Reserve. Given our assumptions that the central bank additionally adjusts its policy based on the stance of the labor market and that the effect of monetary policy reacts with a lag to the labor market, the employment variable (E_t) is ordered after GDP and inflation. The employment variable is consequently ordered before the Shadow variable as we assume that monetary policy reacts contemporaneously to the employment-to-population ratio. This is line with previous literature by Carpenter & Rodgers III (2004). The Gini index is ordered before the Shadow rate, as in our baseline model. This model is not sensitive towards the ordering of the two variables, Gini index and Shadow rate, which also was true for the baseline model. Christiano et al. (1994) argue that labor market variables could be ordered before the monetary policy variable as the labor market variable is an indicator of the level

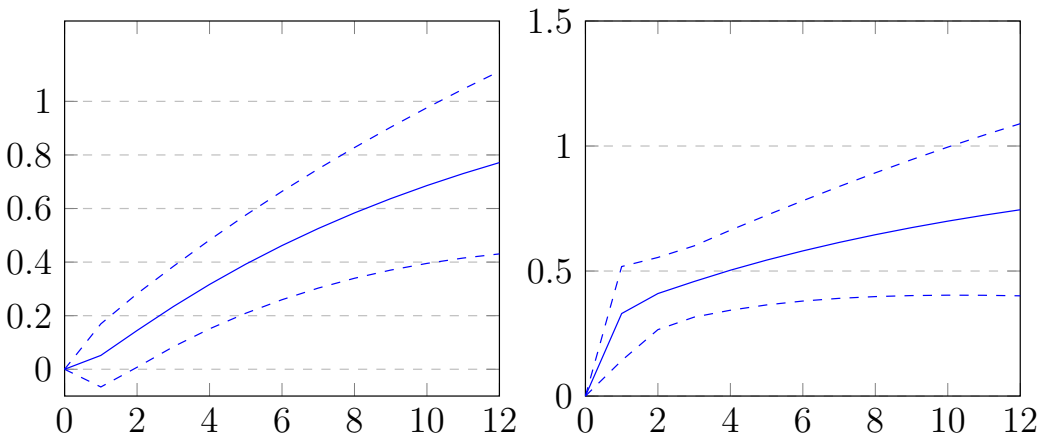
[25] Piketty (2014) utilizes tax returns data and place focus on the upper income bracket
[26] See *subsection 6.2.7*

of aggregate output.

Our extended VAR model is estimated with a lag order of one, suggested unambiguous by all chosen information criteria, reported in *table 11*.

Information Criteria	**Lags**		
	1	**2**	**3**
AIC	**-680.6**	-660.3	-659.18
BIC	**-628.8**	-578.5	-549.5
HQC	**-665.2**	-636.7	-628.754

Table 11: Lag Selection by Information Criteria, Employment VAR



(a) Employment/Population (b) Gini index (total income)

Figure 20: Orthogonalized IRF of Monetary Policy Shock, Labor Market Model Ordering: GDP, Inflation, Employment, Gini (total income), Shadow rate

Figure 20 indicates that a negative innovation to the Shadow Federal Funds rate increases the employment-to-population rate. The IRF demonstrates that employment remains more or less unchanged until after approximately one quarter and then gradually starts to incline, and the effect persists throughout the projected period. The Gini index reacts in a similar pattern, except for a sharper initial increase. Our results indicate that an expansionary monetary policy shock increases employment, while increasing income inequality.

Hence, our results imply that there are factors, such as the labor market that are working against an increasing level of inequality. Questions might be raised as to whom the increasing employment is gaining. Naturally, this might also increase employment for the upper decile. However, theory suggests, which we also find plausible, the benefits of reduced unemployment are stronger for those with lower income.

Furthermore, we expect the lower part of the income distribution to be more sensitive to business cycles, and thus facing a higher risk of unemployment after a downfall. Hence, one could argue that both the lower and upper part of the income distribution were better off with the monetary policy stimulus.

The findings in the above model are similar to the results of previous literature by Christiano et al. (1994), Carpenter & Rodgers III (2004) and Bernanke & Blinder (1992), who include additional variables to demonstrate the transmission of monetary policy actions on income inequality through its influence on the labor market, focusing on conventional monetary policy. Christiano et al. (1994) provide evidence that a positive Federal Funds shock forces employment to steadily decline. Carpenter & Rodgers III (2004) report a decrease in the employment-to-population ratio. According to their studies, this is mainly attributed to an increased unemployment rate. Bernanke & Blinder (1992) argue that unemployment rise with a nine months delay after a contractionary monetary shock on the Federal Funds rate. Blanchard & Katz (1996) provide further evidence that low-skilled labor supply is more exposed than skilled workers to changes in labor supply following an economic slow-down.

The labor market effect has been highlighted as one of the main counterarguments for exacerbated inequality within the United States as a consequence of the Federal Reserve's policy. Even if the policy has boosted the income of richer households through its effect on the financial market, it may have prevented an increased level of unemployment, as well as other positive macroeconomic effects.

Supporting this argument is Draghi (2016), who recently stated in a speech at the

German Institute for Economic Research: *"Most importantly, it reduces unemployment, which benefits poorer households the most. For this reason, research from the US and UK has shown that monetary policy actions that boost the economy typically reduce income inequality over the cycle."*

In this paper, we have investigated the short-run implications, where our findings mainly support that reducing unemployment through expansionary policy is beneficial for the lower income bracket. However, caution should be paid to draw conclusions about the long-term solutions based on these results. Romer & Romer (1998) focus on expansionary monetary policy shocks and the effect on poverty. The paper concludes that the short run effect of an expansionary policy boom is better conditions for the poor. Yet, in the long run, a low inflation and stable growth policy is likely create better conditions for the poor.

8 Conclusion

This paper has investigated the relationship between unconventional monetary policy and income disparity. We have provided evidence that an accommodative monetary policy shock increases income inequality in the short-run. The policy has received criticism for benefiting the richer part of the population and consequently increasing inequality. However, as discussed in the previous literature section, there are still disagreements about the true side-effects of the policy. The implementation of quantitative easing has caused a heated debate among scholars, media, politicians and economists.

Over the last decades, the United States has witnessed an increasingly inegalitarian society. Our motivation was to investigate whether unconventional monetary policy has played a role in the enlarged income gap. In an attempt to quantify the effects, we estimated a VAR model, to assess the overall impact but also to examine the underlying channels in further detail. In particular, we estimated extended models that highlighted the impact of the stock and labor market through the income composition, financial segmentation and earnings heterogeneity channels.

Our results from the baseline 90/10 model indicate that during an expansionary monetary policy shock, the income of different households is affected disproportionately. The income distribution was further examined by decomposing the distribution into the poorest 10 percent, the low to median households and the richest 10 percent to provide a richer picture of the inequality. For those at the lower end of the income ladder the policy is recognized to have a negative impact on their average income level. However, the reduction of unemployment during such a regime is suggested to benefit the poorer more than those at the higher end, mitigating some of the unwanted distributional effects.

In contrast, we get indications that those situated at the upper tail of the income distribution are affected in the opposite direction, increasing their total average income. That is, to the extent that these households have a higher concentration of

their income from the assets market than those at the lower end. We attribute this effect to the portfolio re-balancing channel of the quantitative easing mechanism. The stock market model indicates that the an innovation to the Shadow Federal Funds rate increases S&P500 earnings. Households with a larger share of financial income will consequently benefit most from these unconventional policies.

Overall, we provide evidence that monetary policy has played a considerable role in the increasingly widened income gap. Measuring the overall inequality through the Gini index, we find that the policy accounts for 59 percent of the variations in the income inequality after two years. Comparing the effects to conventional policies, we observe distinctly different results. We do not find strong effects on income inequality of a negative innovation to the traditional policy interest rate. Unconventional policies consequently seem to explain a larger share of the variations to income inequality compared to the more traditional regime. In general, our results persist after accounting for different income inequality measurements and ordering between the main variables of interest.

This paper has contributed to the literature by the construction and application of a higher frequency income inequality measure for the analysis. Additionally, we have applied the Wu & Xia (2016) Shadow Federal Funds rate as a measure for unconventional monetary policy, an approach previously not used in this context.

We see potential for further research on some of the aspects of this topic. First, an interesting extension to our study would be to compare the results based on data from the CEX to a different source of income data, such as the Current Population Survey. Secondly, to meet the limitations of income data, composing a comprehensive database including tax return and household survey data, would have enriched the income inequality measure with income on the top percentiles. Thirdly, the research could be extended by the inclusion of household characteristics such as education, age and distribution of wealth. In order to determine the true effects of quantitative easing, a more thorough approach would be to include consumption and expenditure inequality in the VAR analysis as examined by Coibion et al. (2012)

for the conventional regime.

In the light of our results and analysis we believe that a further assessment of the weights and relevance of the different channels is needed.

The potential normative perspective from the Federal Reserve on the issue is a natural extension to the debate. The central bank is an independent actor addressing issues related to the mandate and objectives it is given. The Federal Reserve is constrained by the statutory objectives set by the Congress, which focus on stabilizing prices and employment. The income distribution and other social issues have been a concern of fiscal policy and not a direct mandate for the monetary policy of the Federal Reserve. Still, issues related to rising inequality has over the last years been topic for speeches from central bankers such as Janet Yellen (2014) and Mario Draghi (2016). The attention from these policymakers demonstrates that the debate is a non-trivial one.

Despite the widened concern for inequality and the results of our analysis, unconventional monetary policy needs to be viewed in relation to its counterfactual, i.e. what the case would have been if the central bank did not intervene (Bivens 2015). The Federal Reserve argues that it did what was required to stimulate the economy at the time being. It was a necessarily tool to revive the economy during financial distress when the interest rates were exhausted. A passive monetary policy, without any further fiscal stimulus would potentially have made the economy worse off.

Our results indicate that unconventional monetary policy has contributed to the rise in income disparity in the short-run, however it is reasonable to believe that the positive macroeconomic effects of unconventional monetary policy might offset some of the negative distributive effects in the medium term.

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